UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6

RECORD OF DECISION

GULFCO MARINE MAINTENANCE SUPERFUND SITE
TXD055144539
FREEPORT, BRAZORIA COUNTY, TEXAS

SEPTEMBER 2011

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ABBREVIATIONS AND ACRONYMS

95% UCL	95% Upper Confidence Limit of the Arithmetic Mean
ATSDR	Agency for Toxic Substances and Disease Registry
ARARs	Applicable or Relevant and Appropriate Requirements
AOC	Area of Concern
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
bgs	Below the Ground's Surface
CSF	Cancer Slope Factor
cm/sec	Centimeters per Second
COC	Chemicals of Concern
COI	Chemical of Interest
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIP	Community Involvement Plan
CSM	Conceptual Site Model
COPC	Contaminant of Potential Concern
m^3/day	Cubic Meters per Day
m^3/kg	Cubic Meters per Kilogram
yd^3	Cubic Yards
DQO	Data Quality Objectives
days/year	Days per Year
ºF	Degrees Fahrenheit

DNAPL	Dense Nonaqueous Phase Liquid
cis-1,2-DCE	cis-1,2-dichloroethene
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
ERAGS	Ecological Risk Assessment Guidance for Superfund
ELCR	Excess Lifetime Cancer Risk
EPC	Exposure Point Concentration
FS	Feasibility Study
gpm	Gallons per Minute
g/day	Grams per Day
GWBU	Ground Water-Bearing Unit
Site	Gulfco Marine Maintenance Superfund Site
HI	Hazard Index
HQ	Hazard Quotient
IC	Institutional Control
IEUBK	Integrated Exposure Uptake Biokinetic Model
J&E VIM	Johnson and Ettinger Vapor Intrusion Model
kg	Kilogram
LNAPL	Light Nonaqueous Phase Liquid
LOAEL	Lowest Observed Adverse Effects Level
MCL	Maximum Contaminant Level
MSSL	Medium-Specific Screening Level (EPA Region 6)
MSL	Mean Sea Level
µg/dL	Micrograms per Deciliter
µg/kg	Micrograms per Kilogram
µg/L	Micrograms per Liter
mg/kg	Milligrams per Kilogram
mg/kg-day	Milligrams per Kilogram per Day
mg/L	Milligrams per Liter
mg/cm^2	Milligrams per Square Centimeters
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEDR	Nature and Extent Data Report
NAPL	Nonaqueous Phase Liquid
NOAEL	No Observed Adverse Effects Level
NPL	National Priorities List
OU	Operable Unit
O&M	Operations and Maintenance
PBW	Pastor, Behling & Wheeler, LLC.
PAH	Polycyclic Aromatic Hydrocarbons
PRP	Potentially Responsible Party
PSV	Preliminary Screening Values
PCL	Protective Concentration Level

POTW	Publicly-Owned Treatment Works
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RfD	Reference Dose
RAO	Remedial Action Objective
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RCRA	Resource Conservation and Recovery Act
SLERA	Screening Level Ecological Risk Assessment
SVOC	Semivolatile Organic Compound
SF	Slope Factor
cm^2	Square Centimeters
PCE	Tetrachloroethene
TCEQ	Texas Commission on Environmental Quality
TNRCC	Texas Natural Resource Conservation Commission
TPDES	Texas Pollutant Discharge Elimination System
TRRP	Texas Risk Reduction Program
TCE	Trichloroethene
1,1,1-TCA	1,1,1-trichloroethane
1,2,3-TCP	1,2,3-trichloropropane
RAGS	Risk Assessment Guidance for Superfund
SLERA	Screening Level Ecological Risk Assessment
TBC	To Be Considered
TRV	Toxic Reference Value
EPA	United States Environmental Protection Agency (Region 6)
VC	Vinyl Chloride
VOC	Volatile Organic Compound

PART 1: THE DECLARATION

1.0 SITE NAME AND LOCATION

The Gulfco Marine Maintenance Superfund Site (hereinafter "the Site") is located in Freeport, Brazoria County, Texas (Figure 1 – Site Location Map). The National Superfund Database Identification Number is TXD055144539. The Site was finalized on the National Priorities List (NPL) on May 30, 2003.

2.0 STATEMENT OF BASIS AND PURPOSE

This Record of Decision (ROD) explains the factual and legal basis for the United States Environmental Protection Agency's (EPA, Region 6) "Selected Remedy" for the Site. The Selected Remedy for the Site is Alternative 2 (Ground Water Controls and Monitoring). This ROD is also the official documentation of how the EPA considered the remedial alternatives identified for the Site and why the EPA selected the final remedy. This ROD was developed in accordance with the Comprehensive Environmental Response, Compensation and Liability Act, as amended (CERCLA), 42 United States Code (U.S.C.) Sections 9601-9675, and to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300.

The EPA's decision is based on the Administrative Record for the Site, which has been developed in accordance with Section 113(k) of CERCLA, 42 United States Code §9613(k). This Administrative Record file is available for review at the Freeport Branch Library in Freeport, Texas; at the Texas Commission on Environmental Quality ("TCEQ" or "State of Texas" or "State") Records Management Center in Austin, Texas; and at the EPA (Region 6) Records Center in Dallas, Texas. The Administrative Record Index identifies each of the items comprising the Administrative Record upon which the Selected Remedy is based. The State of Texas concurs with the Selected Remedy for the Site.

3.0 ASSESSMENT OF THE SITE

The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment. The Site was contaminated as a result of former barge cleaning operations conducted at the Site. The contaminants found at elevated levels at the Site include volatile organic compounds (VOCs) such as chlorinated solvents and benzene; semi-volatile organic compounds (SVOCs) such as naphthalene; polynuclear aromatic hydrocarbons (PAHs); and metals including arsenic, iron and lead. The former surface impoundments located at the North Area of the Site, which contained contaminated sludges from the barge cleaning operations, were certified closed by the Texas Water Commission, a predecessor of the TCEQ, on August 24, 1982. Ground water in the upper two water-bearing units at the Site is contaminated in the area of the closed impoundments, but investigations indicate that the contaminated ground water plume is currently stable and not moving significantly. Site investigations also indicate the likely presence of non-aqueous phase liquids (NAPL) in the contaminated ground water. The Site ground water is not potable, but the VOCs in the ground water present a risk of creating indoor vapor intrusion in buildings. The Site is currently not in use, but the past and anticipated future use would be industrial/commercial land use.

4.0 DESCRIPTION OF THE SELECTED REMEDY

The Selected Remedy for the Site is Alternative 2 (Ground Water Controls and Monitoring). The estimated present worth cost is $230,000. The components of this alternative are described in detail in Section 19.0 (Selected Remedy) of this ROD. The major components of this alternative are:

1. Review and evaluation of the current restrictive covenants prohibiting ground water use at the Site and requiring commercial/industrial land use and protection against indoor vapor intrusion for building construction on Lots 55, 56, and 57;

2. Modification of the existing Institutional Controls (ICs) to address any issues identified with the current restrictive covenants after review, identify the type and location of hazardous substances, identify the location of the existing cap and restrict actions that might affect the integrity of the cap, and any other necessary modifications;

3. A cap over the former surface impoundments;

4. Annual ground water monitoring, and monitoring as a part of the Five-Year Reviews, to confirm stability of the affected ground water plume; and

5. Implementation of an Operation and Maintenance Plan to provide ground water monitoring and inspection/repair of the cap covering the former surface impoundments.

The Selected Remedy addresses the Remedial Action Objectives (RAOs) developed in accordance with the findings of the Baseline Human Health Risk Assessment, as described in more detail in Part 2 (Decision Summary) of this ROD. These objectives are: 1) to prevent further migration of the VOC and SVOC plumes in Zones A and B, both in terms of lateral extent and the absence of impacts above screening levels to underlying ground water-bearing units; 2) to prevent human exposure to VOCs in any future buildings at levels posing an unacceptable risk for commercial/industrial workers via the ground water to indoor air pathway; 3) to prevent land use other than commercial or industrial; 4) to prevent ground water use; and 5) to prevent potential future exposure to remaining waste material in the former surface impoundments.

While the Remedial Investigation indicated that the contaminated ground water plume is currently stable, the Selected Remedy addresses the RAO of preventing further migration of the contaminated ground water plumes through monitoring to verify that there is no future migration. If, in the future, the VOC and SVOC plumes in Zones A and B do become more mobile, this will be identified through the monitoring and could be addressed by additional response actions, if necessary. Monitoring also addresses the RAO of maintaining protection against potential exposures to VOCs at levels posing an unacceptable risk to commercial/industrial workers via the ground water to indoor air pathway by using the monitoring component to identify if VOC plume expansion is occurring. The Selected Remedy uses institutional controls to address the RAOs of insuring future use of the Site is restricted to industrial/commercial land use, preventing future use of the Site ground water, and preventing human exposure through the ground water to indoor air pathway. Institutional controls will address, in addition, the RAO of preventing future exposure to the remaining waste materials under the cap on the former surface impoundments by restricting activities that might affect the cap's integrity. The cap's integrity will be insured by the implementation of repair and maintenance activities under the Operation and Maintenance Plan. Finally, the existence of the cap and the continued effectiveness of the cap will increase the likelihood of plume stability by preventing water from infiltrating through the materials under the cap, causing leaching to the ground water and potentially accelerating plume migration. The cap also addresses the RAO of preventing future exposure to the remaining waste material in the former surface impoundments.

The Selected Remedy does not provide for treatment of the NAPL in Site ground water. As discussed in more detail in Part 2 (Decision Summary) of this ROD, Alternative 3, the only identified remedial alternative that might address treatment of NAPL, would not be effective in treating NAPL at the Site because the NAPL is dispersed in the Site ground water and difficult to locate and extract.

The Selected Remedy, and the rationale for its selection, is described in more detail, in Part 2 (Decision Summary) of this ROD.

5.0 STATUTORY DETERMINATIONS

The Selected Remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate to the remedial action, is cost-effective, and uses permanent solutions and treatment or resource recovery technologies to the maximum extent practicable. The remedy does not satisfy the statutory preference for treatment, and does not reduce the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as a principal element through treatment. The ROD discusses how the Selected Remedy meets, or does not meet, the statutory requirements, and the rationale for its selection. Because hazardous substances, pollutants, or contaminants will remain at the Site above levels that allow for unlimited use and unrestricted exposure, the EPA will conduct reviews every five years from the start of the remedial action to ensure the remedy protects human health and the environment as described in Section 121 of CERCLA.

6.0 DATA CERTIFICATION CHECKLIST

The following information is included in “The Declaration” (Part 1) and “The Decision Summary” (Part 2) sections of this ROD, while additional information concerning the EPA’s selection of the final remedy can be found in the Administrative Record file for this Site. The following information contains certain key remedy selection information and serves as a “roadmap” to the pertinent information in the ROD:

a. Chemicals of Concern (COCs) and their respective concentrations:

- Section 12.6 – Nature and Extent of Contamination
- Section 14.1.1 – Identification of Potential Chemicals of Concern
- Section 14.1.8 – Risk Characterization
- Section 19.4.3 – Final Cleanup Levels

b. Baseline risk represented by the COCs:

- Section 14.1 – Summary of the Baseline Human Health Risk Assessment
- Section 14.1.8 – Risk Characterization
- Section 14.1.10 – Conclusions of Baseline Human Health Risk Assessment
- Section 14.2 – Summary of the Ecological Risk Assessment
- Section 14.2.9 – Risk Characterization - Risk Estimation and Risk Description (Step 7)
- Section 15.2 – Risks Addressed by the Remedial Action Objectives

c. Remediation goals established for the COCs and the basis for the goals:

- Section 15.0 – Remedial Action Objectives
- Section 15.1 – Basis and Rationale for the Remedial Action Objectives
- Section 15.2 – Risks Addressed by the Remedial Action Objectives
- Section 16.2.2 – Alternative 2: Ground Water Controls and Monitoring
- Section 19.2 – Description of the Selected Remedy
- Section 19.4.3 – Final Cleanup Levels

d. How source materials constituting principal threats are addressed:

- Section 9.1.1 – Closure of the Former Surface Impoundments
- Section 18.0 – Principal Threat Wastes
- Section 20.5 – Preference for Treatment as a Principal Element

e. Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of ground water used in the Baseline Human Health Risk Assessment, Screening Level Ecological Risk Assessment, and this ROD:

- Section 13.1 – Current and Potential Future Land Uses
- Section 13.2 – Current and Potential Future Ground Water Uses
- Section 19.4.1 – Available Land Uses
- Section 19.4.2 – Available Ground Water Uses

f. Potential land and ground water use that will be available at the Site as a result of the Selected Remedy:

- Section 13.1 – Current and Potential Future Land Uses
- Section 13.2 – Current and Potential Future Ground Water Uses

- Section 19.4.1 – Available Land Uses

- Section 19.4.2 – Available Ground Water Uses

g. Estimated capital, lifetime operations and maintenance (O&M), and total present worth costs; discount rate; and the number of years over which the remedy cost estimates are projected:

- Section 16.2.2 – Alternative 2: Ground Water Controls and Monitoring

- Section 19.3 – Cost Estimate for the Selected Remedy

- Table 2 – Alternative 2 Preliminary Cost Projection

h. Key factor(s) that led to selecting the remedy and how the remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria of the NCP:

- Section 14.3 – Basis for Remedial Action

- Section 15.1 – Basis and Rationale for the Remedial Action Objectives

- Section 17.3 – Long-Term Effectiveness and Permanence

- Section 17.4 – Reduction of Toxicity, Mobility, or Volume through Treatment

- Section 17.5 – Short-Term Effectiveness

- Section 17.6 – Implementability

- Section 17.7 – Cost

- Section 17.8 – State Acceptance

- Section 17.9 – Community Acceptance

- Section 17.10 – Summary of Comparative Analysis of Alternatives

- Section 19.1 – Summary of the Rationale for the Selected Remedy
- Section 19.4 – Expected Outcomes of the Selected Remedy

7.0 AUTHORIZING SIGNATURE

This ROD documents the EPA's Selected Remedy for the Gulfco Marine Maintenance Superfund Site. This remedy was selected by the EPA with the concurrence of the TCEQ. The Director of the Superfund Division (EPA, Region 6) has been delegated the authority to approve and sign this ROD.

United States Environmental Protection Agency (Region 6)

By: ______________________________ Date: ____________

Samuel Coleman, P.E., Director
Superfund Division (6SF)

CONCURRENCE PAGE FOR RECORD OF DECISION
GULFO MARINE MAINTENANCE SUPERFUND SITE

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PART 2: THE DECISION SUMMARY

This Decision Summary provides a description of the Site-specific factors and analyses that led to the selection of the remedy for the Site. It includes background information about the Site, the nature and extent of contamination found at the Site, the assessment of human health and environmental risks posed by the contaminants at the Site, and the identification and evaluation of remedial action alternatives for the Site.

8.0 SITE NAME, LOCATION, AND OPERATIONAL HISTORY

The Site (See Figure 1 – Site Location Map), which is located within the city limits of Freeport, Brazoria County, Texas, consists of approximately 40 acres along the north bank of the Intracoastal Waterway between Oyster Creek and the Texas Highway 332 bridge, located approximately one mile to the east and west of the Site, respectively. The Site includes approximately 1,200 linear feet (ft.) of shoreline on the Gulf Intracoastal Waterway. The population of Brazoria County is approximately 242,000, with approximately 12,700 residents in Freeport according to the 2000 U.S. Census.

Marlin Avenue, which runs approximately east to west, divides the Site into two primary areas (See Figure 2 – Site Map). The property to the north of Marlin Avenue, or the North Area, consists of undeveloped land and the closed surface impoundments, while the property south of Marlin Avenue, or the South Area, was developed for industrial uses with multiple structures, a dry dock, sand blasting areas, a former aboveground storage tank (AST) tank farm, and two barge slips connected to the Intracoastal Waterway. The North Area is zoned as “M-2, Heavy Manufacturing.” The South Area is zoned as “W-3, Waterfront Heavy” by the City of Freeport. This designation provides for commercial and industrial land use, primarily port, harbor, or marine-related activities. Institutional controls in the form of restrictive covenants prohibiting any land use other than commercial or industrial and prohibiting ground water use have been filed for all parcels within both the North and South Areas. Additional restrictions requiring any building design to preclude indoor vapor intrusion and requiring EPA and TCEQ notification prior to any building construction have been filed for Lots 55, 56 and 57 of the North Area.

Adjacent property to the north, west, and east of the North Area is unused and undeveloped. Adjacent property to the east of the South Area is currently used for industrial purposes. The property to the west of the South Area is currently vacant and previously served as a commercial marina. The Intracoastal Waterway bounds the Site to the south. Residential areas are located south of Marlin Avenue, approximately 300.0 ft west of the Site, and 1,000 ft east of the Site.

The South Area includes approximately 20 acres of upland that was created from dredged material from the Intracoastal Waterway. Some of the North Area is upland created from dredge spoil, but most of this area is considered wetlands by the United States Fish and Wildlife Service. The Intracoastal Waterway design width and depth in the vicinity of the Site, based on United States Army Corps of Engineers mean low tide datum, is 125.0 ft wide and 12.0 ft deep.

8.1 Site Operations

The Site operated as a barge cleaning and repair facility from 1971 to about 1998 under several ownerships. Barges brought to the facility were cleaned of waste oils, caustics, and organic chemicals. Three surface impoundments in the North Area were used for storage of these materials and waste wash waters generated during barge cleaning activities until 1981. The impoundments were closed in 1982. The shallow ground water, consisting of salt water unfit for human consumption, below the former impoundments was investigated and found to contain various organic chemicals.

Pre-barge cleaning operations were associated with dredge spoiling activities in the area to the south of the Site. Dredge spoils from the Intracoastal Waterway can be seen in historical photographs of the southern part of the Site. Deed records for specific lots on the Site conveyed an easement to United States for the work of “constructing, improving, and maintaining an Intracoastal Waterway”, and for “the deposit of dredged material.”

Additionally, off-shore oil platform fabrication work was performed in the northeast part of the South Area during the early 1960s. Raw materials and supplies were brought onto the Site, the platform fabrication work (*i.e.*, welding, metals cutting, etc.) was performed, and the finished products and any unused materials and supplies were removed from the Site.

9.0 SITE HISTORY AND ENFORCEMENT ACTIVITIES

This section of the ROD provides the history of Federal and State investigations and the EPA’s removal, remedial, and enforcement activities conducted at the Site. The EPA is the lead agency for the Site removal and remedial activities. The TCEQ is the support agency for these activities.

9.1 History of Federal and State Investigations and Remedial Actions

Federal and state entities have conducted several studies and cleanup actions at the Site and performed actions to investigate the Site’s contamination.

9.1.1 Closure of the Former Surface Impoundments

The Texas Water Commission (TWC), a predecessor of the TCEQ, certified closure of the surface impoundments, located at the North Area, on August 24, 1982. The former surface impoundments consisted of three earthen lagoons used for the storage of wash waters generated from barge cleaning operations. Covering an area of approximately 2.5 acres combined, the impoundments were reportedly three feet deep with a natural clay liner. The closure activities included the removal of liquids and most of the sludges, solidification of approximately 100 cubic yards of residual sludge that was difficult to excavate, and capping with three feet of clay and a hard-wearing surface (*i.e.*, shell). While not described in detail at the time of closure, the sludges and other materials covered by the cap would appear to include VOCs and SVOCs such as those found in the Site ground water. These prior closure activities support the Selected Remedy described in this ROD and are discussed further in Sections 18.0 (Principal Threat Wastes) and 20.5 (Preference for Treatment as a Principle Element).

During the Remedial Investigation, four soil borings were drilled through the cap of the former surface impoundments and the soil samples were tested to evaluate the construction materials and thickness of the cap. The surface impoundment cap thicknesses at the four boring locations ranged from 2.5 to greater than 3.5 ft. The geotechnical properties (*i.e.*, Atterberg Limits and percent passing a # 200 sieve) of the cap material are consistent with those recommended for industrial landfill cover systems in TCEQ's technical guidelines. The vertical hydraulic conductivities were all less than the TCEQ's guideline value of 1.0×10^{-7} cm/sec.

9.1.2 Health Assessments

A Public Health Assessment (PHA) was prepared for the Site in 2004 by the Texas Department of Health (TDH) for the Agency for Toxic Substances and Disease Registry (ATSDR). The PHA concluded that contaminants in soil, sediment, and ground water pose no apparent public health hazards, but the overall public health hazard could not be determined due to a lack of data for all pathways.

A Health Assessment (HA) was prepared for the Site in February 13, 2008, by the TDH for the ATSDR. The HA concluded that, "Based upon our analysis of the November and December 2006 data, we do not expect to see health effects associated with exposure to contaminants in fish and crab collected from the Intracoastal Waterway near the Gulfco Marine Maintenance Superfund Site. Therefore, consumption of fish and crab from the Intracoastal Waterway poses no apparent public health hazard."

9.1.3 Unilateral Administrative Order

The EPA issued a Unilateral Administrative Order (UAO, EPA 2005), effective July 29, 2005, to the Site potentially responsible parties (PRPs) to perform a Remedial Investigation to define the nature and extent of contamination at the Site and to prepare a Feasibility Study to identify and screen remedial action alternatives. The Remedial Investigation, Feasibility Study, Baseline Human Health Risk Assessment, Baseline Ecological Risk Assessment, and Screening

Level Ecological Risk Assessment Reports completed pursuant to the UAO support the EPA's Selected Remedy described in this ROD.

9.2 CERCLA Removal Action

The EPA issued an Administrative Settlement Agreement and Order on Consent for Removal Action (Settlement Agreement, EPA 2010) on October 26, 2010, which addressed the former AST Tank Farm located in the South Area. The Settlement Agreement required the removal of the ASTs that contained hazardous substances that were left from the barge cleaning operations. The removal work began in November 2010 and was completed by March 2011.

9.2.1 Removal Action Summary

The Removal Action included characterization and management of water accumulated in the AST Tank Farm containment areas; removal and disposal of liquid wastes from the tanks; and solidification, removal, and disposal of non-liquid (*i.e.*, solids and sludge) wastes from the ASTs. The tanks were subsequently demolished following removal of the wastes and decontamination. The concrete containment berms at the North and South Containment Areas were breached so that rainfall would freely drain from the structures. Piping, metal "cat-walks," a steel hopper-like structure located within the North Containment Area, and a metal walled structure located immediately east of the North Containment Area were demolished and removed. The Removal Action also included an asbestos survey, and the removal and disposal of debris and contaminated soil located inside and east of the containment areas. The Removal Action objectives of protecting the public health, welfare, or the environment, set forth in the Settlement Agreement, were met through the performance of the Removal Action activities documented in the Final Removal Action Report (PBW 2011a).

9.2.2 Management of Accumulated Water

Following confirmation that the water in the containment areas met the discharge criteria and prior to commencing other Removal Action activities, approximately 15,000 and 13,500 gallons of water from the North and South Containment Areas, respectively, were discharged to the Intracoastal Waterway. Following a rain event at the Site, a total of approximately 17,000 gallons of accumulated water, that met the discharge criteria, was also discharged from the South Containment Area into the Intracoastal Waterway. The analytical results for a North Containment Area water sample did not meet the discharge criteria and a total of approximately 6,800 gallons of impacted water were pumped from the North Containment Area into tanker trailers and transferred off-site for disposal. After Site restoration was completed, water from the North and South Containment Areas which met the discharge criteria was released by breaching the walls of the containment areas.

9.2.3 Asbestos Inspection

The Removal Action also consisted of an inspection for potential asbestos containing materials (ACM) within the former AST Tank Farm. Samples were collected from seven potential ACM locations. These samples included debris, gaskets, and insulation material. One of the samples collected was found to contain friable asbestos in a flange gasket located on the east end of Tank No. 10. The flange was removed and properly disposed off-site.

9.2.4 Liquid Wastes Handling and Disposal

Approximately 74,500 and 14,150 gallons of aqueous and non-aqueous (hydrocarbons) liquids, respectively, located within the ASTs, were transported off-site for incineration.

9.2.5 Solid Wastes Handling and Disposal

Following the removal of liquids from all of the ASTs, a combination of cutting torches and hydraulic shears were used to open the tanks to allow for solidification of the remaining sludges and solids. Solidification to the point that there were no free liquids in the wastes was required by the disposal facility, and was accomplished by adding and mixing fly ash to tank contents after liquids were removed. A total of approximately 210,000 pounds of fly ash was required to facilitate solidification. Once sufficiently solidified, the sludge was transferred to watertight hazardous waste containers (roll-off boxes) lined with sealable water-tight liners. Approximately 829,364 pounds of hazardous solids were transported off-site for incineration.

9.2.6 AST Decontamination, Demolition, and Disposal

After all sludge was removed, the tanks were cleaned by scraping, brushing, steam-cleaning, and, when necessary, spraying and brushing with surfactants to remove any remaining oily residue. The tanks were then disassembled using a cutting torch or hydraulic shears and crushed with a track hoe. All tanks were demolished on-site, except for Tank No. 14 which was a thick walled tank (greater than 1-inch thick steel). Tank No. 14 had holes cut to render it unusable and was transported offsite in two pieces. All scrap metal from the Removal Action, including tanks and tank pieces, were transported off-site for recycling.

9.2.7 South Containment Area Decontamination

The South Containment Area was cleaned and decontaminated following the removal of all tanks and debris. The sediment on the concrete floor was scraped and removed, and the concrete walls and floor of the containment area were pressure washed with a steam cleaner. The removed sediment was sampled and classified as non-hazardous. The mud and sediment from the trenches, located on portions of the north end of the South Containment Area, were vacuumed to the depths at which clay was encountered. The concrete walls of the trenches were then pressure washed. After decontamination of the South Containment Area was complete, two verification samples were collected from the clay floor of the trenches which were subsequently backfilled with sandy clay soil imported from an off-site quarry. The mud, sediment, and water that were collected were transported off-site for disposal as non-hazardous wastes.

9.2.8 North Containment Area Decontamination

The floor of the North Containment Area, which was constructed of four to eight inches of caliche-like base material underlain by clay, was visibly stained with hydrocarbons beneath four of the tanks. Surficial staining was present beneath the two large ASTs (Tanks Nos. 15 and 21). More extensive staining was evident beneath Tank No. 6, which, when removed, was found to have several holes in its base. Staining was also observed below the footprint of Tank No. 2, located adjacent to Tank No. 6; however, the staining was believed to be associated with releases from Tank No. 6. As a measure to ensure future water accumulated in the North Containment Area would not become impacted by residual contaminants on the caliche floor of the containment area, the North Containment Area floor surface was scraped using a small front-end loader. The removed surface material scrapings were stockpiled and later loaded into two roll-off boxes, then sampled and characterized for disposal. Based on the characterization sample results, the North Containment Area floor scrapings were classified as hazardous.

Visibly impacted soil extended from the surface to approximately 5.5 ft below the ground's surface (bgs) at specific locations beneath the former location (footprint) of Tank No. 6. Near the south end of the Tank No. 6 footprint, the impacted soil extended to the west beneath the south end of the former location of Tank No. 2, where soil was excavated to approximately 2.5 ft bgs. Beneath the remainder of the Tank No. 2 footprint there were no visible impacts at a depth of approximately 1.0 ft bgs, and the excavation was terminated at that depth. During the excavation of the area beneath Tank Nos. 2 and 6, the subsurface material present from the ground's surface to approximately 2.0 to 2.5 ft bgs was observed to consist of fill material which included caliche-based material and clay. Outside of the footprints of Tank Nos. 2 and 6, this fill material was not visibly impacted. There was no visible staining below 2.5 ft bgs south and west of Tank No. 2, except for a thin (approximately 0.2 ft) zone of black staining along the contact between the base of the fill and original ground surface. Approximately the southern two-thirds of the area beneath the Tank No. 6 footprint was excavated to a depth of approximately 5.5 to 6.0 ft bgs. In the south and east walls of the excavation visibly impacted soils were present from approximately 2.5 ft bgs to approximately 5.5 ft bgs. In this deepest portion of the excavation, a clay soil with no visible impacts was present from approximately 5.5 to 6.0 ft bgs. Beneath the northern end of the Tank No. 6 footprint, visibly impacted soil was excavated to approximately 2.0 ft bgs. At that depth visible impacts were limited to localized areas.

Very well compacted and hard caliche was encountered beneath the Tank Nos. 15 and 21 footprints. These areas were scraped using a trackhoe to remove surficial staining. Approximately 3.0 to 4.0 inches of caliche were scraped from the footprint of both former tanks. Below both of the footprints of Tank Nos. 15 and 21, the staining was observed to extend through the caliche base (6.0 to 8.0 inches) in localized areas, but did not appear to have visibly impacted the underlying clay. Visibly impacted caliche was removed to the extent practical. All excavated soils from the Tank Nos. 2/6 excavation, and the scraped caliche/soil from the Tank Nos. 15 and 21 footprints were classified as hazardous and transported off-site for incineration. After verification samples were collected from the excavated area, the excavation was backfilled with sandy clay soil imported from an off-site quarry and the entire North Containment Area was graded so that accumulated water would drain to the low side.

Verification samples were collected in order to document soil conditions at the North Containment Area following completion of excavation activities These samples were collected after it was determined that impacted soil encountered at depths ranging from approximately 2.5 to 5.5 feet bgs could not be practically excavated such that visible staining was removed. The verification samples were intended to characterize VOC and SVOC concentrations in the residual post-excavation soil. Analytical results for the Site's chemicals of interest from the verification samples were evaluated relative to comparison values, which were established by using the lower of the EPA's Region 6 Soil Screening Criteria value and the TCEQ's Protective Concentration Level for an industrial/commercial exposure scenario. Analytical results for the SVOCs did not exceed comparison criteria for any chemicals of interest at any of the verification sample locations. VOC comparison criteria for benzene, chloroform, trichlorothene (TCE), tetrachloroethene (PCE), and ethylbenzene were exceeded at several verification sample locations, but not at levels presenting an unacceptable risk. Verification samples were also collected from the clay floor of the trenches in the South Containment Area and the soil concentrations did not exceed comparison criteria for the VOCs and SVOCs of interest.

9.3 Enforcement and Potentially Responsible Party Involvement

The PRPs have been involved with the investigation and cleanup of the Site. The PRPs performed the RI/FS for the Site through a 2005 UAO (EPA 2005) and the 2010 Removal Action under a Settlement Agreement (EPA 2010) addressing the former AST Tank Farm at the South Area.

10.0 COMMUNITY PARTICIPATION

This section of the ROD describes the EPA's community involvement and participation activities. The EPA has been actively engaged in dialogue and collaboration with the affected community and has strived to advocate and strengthen early and meaningful community participation during the EPA's remedial and removal activities at the Site. These community participation activities during the remedy selection process meet the public participation requirements in CERCLA and the NCP.

10.1 Community Involvement Plan

The Community Involvement Plan (CIP, EPA 2004)) for the Site was prepared in November 2004. It specifies the outreach activities that the EPA will undertake to address community concerns and expectations. The CIP includes background information on the community, community issues and concerns, community involvement activities, a communication strategy, an official contact list, and local media contacts.

10.2 Community Meetings and Fact Sheets

The EPA and TCEQ have conducted community meetings during the course of the Superfund activities at the Site and have provided public notices of these meetings in order to encourage the community's participation. Community meetings were held in August 2003 and October 2005.

A public meeting was held on August 4, 2011, at 6:30 pm at the Velasco Community House located at 110 Skinner Street in Freeport, Texas. The EPA held this public meeting to explain the Proposed Plan (EPA 2011) and the EPA's preliminary recommendation of implementation of Alternative 2 (Ground Water Controls and Monitoring) for the Site. Oral and written comments were accepted at the meeting. The public comment period began on July 9, 2011, and ended on August 22, 2011. The EPA encouraged the public to participate in the public meeting and to review and comment on the EPA's preliminary recommendation presented in the Proposed Plan.

Fact sheets have been and will continue to be prepared as necessary to provide the public current information about the Site. The EPA has posted a current fact sheet, which provides information about the Site, on the internet at:

http://www.epa.gov/region6/6sf/pdffiles/0602027.pdf

The EPA and TCEQ will continue to provide information regarding the cleanup of the Site to the public through fact sheets, public meetings, the Administrative Record file for the Site, and local newspaper announcements.

10.3 Technical Assistance Grant

The availability of a Technical Assistance Grant (TAG) was published on September 26, 2002, and May 15, 2003. No final applications were received. A TAG provides funding for activities that help a community participate in decision making at Superfund sites.

10.4 Information Repositories

The EPA established information repositories to provide the public a location near their community to review and copy background and current information about the Site. The Remedial Investigation, Feasibility Study, Baseline Human Health Risk Assessment, Screening Level Ecological Risk Assessment Reports, and Baseline Ecological Risk Assessment Reports and other relevant documentation used by the EPA in choosing the Selected Remedy described in this ROD are filed at the Site's local repository and the Federal/State repositories located at:

Freeport Branch Library
410 Brazosport Boulevard
Freeport, TX 77541

U.S Environmental Protection Agency (Region 6)
1445 Ross Avenue, Suite 700
Dallas, TX 75202-2733
Telephone Number: (800) 533-3508

Texas Commission on Environmental Quality
Records Management Center, Central File Room
Technical Park Center Bldg. E, 1st Floor, Room 1003
12100 Park 35 Circle
Austin, TX 78753
Telephone Numbers: (512) 239-2900 and (800) 633-9363

11.0 SCOPE AND ROLE OF OPERABLE UNITS AND RESPONSE ACTION

"Operable Unit" (OU) means a discrete action that comprises an incremental step toward comprehensively addressing problems at a site. The cleanup of a site can be divided into a number of OUs, depending on the complexity of the problems associated with a site.

The EPA has organized the Site into one OU, consisting of the North and South Area, and the actions described in this ROD address all of the contaminated media at the Site and any threats to human health and the environment posed by the conditions at the Site.

12.0 SITE CHARACTERISTICS

This section of the ROD includes a discussion of the demographics and current land use of the Site; the area's climate and topography; the Site's Conceptual Site Model; and the nature and extent of contamination in the soils, ground water, surface water and sediments present at the Site.

12.1 Demographics and Current Land Use

The Site is located within the city limits of Freeport in southeast Brazoria County. The population of Brazoria County is approximately 242,000, with approximately 12,700 residents in Freeport according to the 2000 U.S. Census (USCB, 2009). According to the Site's CIP (EPA 2004), there are 78 residents within 1 square mile of the Site, of which 17.9% are minority and 23.3% are economically stressed. Within a 50-square mile area around the Site, the population is

3,392, of which 33.4% are minority and 24.3% are economically stressed.

The land use for the North Area and South Area of the Site is classified by the City of Freeport Zoning Code. The land use for the North Area is currently zoned as “M-2, Heavy Manufacturing.” This classification allows for manufacturing and industrial activities. The North Area consists of undeveloped land, a former parking area, and the closed surface impoundments. The South Area is currently unused but it is anticipated that the South Area will be used for commercial/industrial purposes in the future. The South Area is zoned as “W-3, Waterfront Heavy.” This classification provides for port, harbor, or marine-related activities including the storage, transport, and handling and manufacturing of goods, materials, and cargoes related to marine activities. The South Area was developed for industrial uses with improvements including multiple structures, a dry dock, two barge slips, a sand blasting area, and a former AST Tank Farm.

12.2 Climate and Topography

Data from the Dow Texas Operations (Freeport, Texas) meteorological station, located approximately 6 miles west of the Site, indicated an average annual rainfall accumulation of 47.94 inches, an average low temperature of 63° F, an average high temperature of 78° F, and a mean annual temperature of 70° F for the 5-year period from 2004 through 2008 (Dow, 2009).

The Site’s topography is very flat consisting of approximately 40 acres along the north bank of the Intracoastal Waterway and is located within the 100-year coastal floodplain (FEMA, 2009). Most of the North Area is considered wetlands although there are some upland areas created from dredged spoil material. The South Area includes approximately 20 acres of upland created from material dredged from the Intracoastal Waterway. Ground surface elevations range from 1.5 feet above mean sea level (MSL) north of the Site to 5.6 feet above MSL within the South Area.

12.3 Conceptual Site Model

A Conceptual Site Model (CSM) is a tabular representation of a site’s conditions that displays:

- The distribution of released contaminants,
- Mechanisms of release,
- Complete and incomplete exposure pathways and migration routes, and
- Potential human and ecological receptors.

A complete exposure pathway has four essential components. Exposure typically does not occur without the presence of all four components. The EPA's guidance defines an exposure pathway as consisting of the following elements:

- A source and mechanism of chemical release to the environment (*i.e.*, a source of contamination),

- An environmental transport medium for the released chemical (*i.e.*, soil),

- A point of potential human contact with the contaminated medium (*i.e.*, an exposure point), and

- A route of exposure at the exposure point (*e.g.*, ingestion, inhalation, or dermal contact).

Figures 3 (Human Health Conceptual Site Model – South Area) and 4 (Human Health Conceptual Site Model – North Area) depict the human health CSMs for the South and North Areas, respectively. These CSMs were used to develop the quantitative exposure assessment of the Baseline Human Health Risk Assessment. Complete pathways are indicated with a bold line and check in the potential receptors column. Incomplete pathways are denoted with an "X" and a footnote indicating why the pathway is incomplete. Figures 5 (Conceptual Site Model – Terrestrial Ecosystem) and 6 (Conceptual Site Model – Aquatic Ecosystem) depict the ecological CSMs for the terrestrial and aquatic receptors at the Site. Incomplete pathways are denoted with an "X." The CSM assumed that the integrity of the cap on the former surface impoundments would continue to be maintained.

At the South Area, potential chemicals of concern (PCOCs) were potentially released from historical Potential Source Areas (PSAs) to the soil and may have migrated to ground water via leaching through the soil column, and to surface water in the Intracoastal Waterway via overland surface runoff. Once in surface water, some compounds tend to stay dissolved in the water whereas some tend to partition to sediment. Volatilization and fugitive dust generation may have caused PCOCs in soil to migrate within the Site or off-site. Exposure to on-site receptors may also occur directly from contact to the soil. However, based on PCOC data for surface soil samples collected on Lots 19 and 20 directly west of the Site and the qualitative screening conducted for the off-site residential receptor, it does not appear that significant entrainment and subsequent deposition of particulates occurred at the Site or at off-site locations. Once in ground water, VOCs may migrate within the ground water and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

At the North Area, PCOCs were potentially released from historical PSAs to the soil and/or may have migrated to ground water. PCOCs may have also migrated from soil to surface water and sediments in the nearby wetlands area via overland surface runoff. Fugitive dust generation was considered a potentially significant transport pathway for PCOC migration on-site and evaluated quantitatively in the BHHRA for the on-site receptors, although this pathway was eliminated during the screening process for the off-site residential receptor. Once in ground water, VOCs may migrate within the ground water and/or volatilize through the soil pore space and be emitted into outdoor or indoor air. It was assumed, as part of the risk assessment, that these media were potentially contacted by the various hypothetical receptors possibly at the Site and, as such, these exposure pathways were potentially complete.

12.3.1 Sources of Contamination

The EPA believes that the ground water contamination at the Site was caused by the historical barge cleaning and wash water disposal operations, and possibly the off-shore oil platform fabrication work operations. The uppermost ground water-bearing unit (GWBU), or Zone A, underlying the North Area contains VOCs, particularly chlorinated solvents, their degradation products, and benzene at concentrations exceeding their “extent evaluation criteria or values.” The extent evaluation criteria are screening levels that were used to determine the extent of contamination. These screening levels were compiled from a number of sources such as the EPA’s Region 6 Media-Specific Screening Levels, TCEQ’s Protective Concentration Levels, surface water quality standards, and federal Maximum Contaminant Levels.

12.3.2 Release and Transport Mechanisms

The physical and chemical characteristics of PCOCs and their potential transport media affect the degree of contaminant persistence and rate of migration within that media. Physical characteristics include parameters such as grain size and moisture content for surface soil particles or residual grit from Site sand-blasting areas. Chemical characteristics include parameters such as soil/water distribution coefficient, adsorption potential and degradation characteristics. These chemical characteristics are specific to each chemical present, and may also be affected by the physical characteristics of the media in which the chemical is present. For air migration pathways, physical characteristics are important because mobilization of soil particles by wind is often a dominant mechanism for potential air transport of contaminants. Chemical characteristics, such as the volatility of a particular PCOC can also be very important for air pathways. In surface water, physical and chemical characteristics are both important because transport may occur in solution or in association with suspended sediment. Dissolved-phase transport is the dominant contaminant migration mechanism in ground water; therefore, chemical characteristics are often most important with respect to that medium.

12.3.2.1 Air Transport Pathway

A possible mode for airborne contaminant transport at the Site is entrainment of PCOC-containing particles in wind. This pathway is a function of particle size, chemical concentrations, moisture content, degree of vegetative cover, surface roughness, size and topography of the source area, and meteorological conditions (*e.g.*, wind velocity, wind direction, wind duration, precipitation, and temperature). Movement of airborne contaminants occurs when wind speeds are high enough to dislodge particles; higher wind velocities are required to dislodge particles than are necessary to maintain suspension.

Potential airborne contaminants at the Site consist predominantly of particles since volatile PCOCs were generally not detected above screening levels in near surface soil samples from the 1.0 to 2.0 foot depth interval and generally would not be expected to persist in surface soils. Thus, potential contaminant transport via air is predominantly in the solid phase. The physical characteristics of the particles govern the potential for airborne migration. The mass of a contaminant transported from a given PSA is also dependent on the contaminant concentrations in surface soil particles.

In general, only fine-grained particles are susceptible to transport in air. PCOCs associated with the scrap metal present in surface fill soils in the South Area and some parts of the North Area would generally not be transported via the air pathway due to the size and density of these materials. Similarly, the predominantly vegetated and moist surface soils/sediments in the North Area are not generally conducive to dust generation and particle transport. The predominant wind direction in the Houston region is from the southeast and south; therefore, potential contaminant migration via the air transport pathway would generally be toward the north and northwest from Site's PSAs. Surface samples in the North Area (Figure 7 – Detected Concentrations Exceeding Vertical Comparison Values, North Area RI Soil Samples), generally downwind from the South Area PSAs most likely to contribute metals to surface particles such as the sand blasting areas (Figure 8 – Potential Source Areas), typically did not indicate elevated concentrations of metals above screening levels, and thus airborne transport from these areas appears limited. Similarly, lead concentrations in surface soil samples collected on Lots 19 and 20 southwest of the Site were relatively low and not indicative of significant air transport of contaminants from Site PSAs via entrainment and subsequent deposition of particles.

12.3.2.2 Surface Water/Sediment Transport Pathways

The primary surface water/sediment pathways for PCOC migration from historical Site PSAs are: (1) erosion/overland flow to wetland areas north and east of the Site from the North Area due to rainfall runoff and storm/tide surge; and (2) erosion/overland flow to the Intracoastal Waterway from the South Area as a result of rainfall runoff and extreme storm surge/tidal flooding events.

Overland flow during runoff events occurs in the direction of topographic slope. Due to the minimal slope at the Site, overland flow during more routine rainfall events is generally low, with runoff generally collecting in many areas of the Site. Extreme storm events can inundate the Site, resulting in overland flow during both storm surge onset and recession. During less extreme storm surge events or unusually high tides, tidal flow to wetland areas on and adjacent to the Site occurs from Oyster Creek northeast of the Site (Figure 1 – Site Location Map). However, more typically the wetland areas are not hydrologically contiguous with Oyster Creek.

Potential contaminant migration in surface water runoff can occur as both sediment load and dissolved load. Therefore, both the physical and chemical characteristics of the contaminants are important with respect to surface-water/sediment transport. The low topographic slope of the Site and adjacent areas is not conducive to high runoff velocities or high sediment loads. Consequently, surface soil particles would not be expected to be readily transported in the solid phase. Additionally, the vegetative cover in the North Area serves to reduce soil erosion and resulting sediment load transport with surface water in these areas. Dissolved loads associated with surface runoff from the North Area would likewise be expected to be generally low due to the absence of exposed PSAs, the low PCOC concentrations in North Area surface soils/sediments (Figures 7 [Detected Concentrations Exceeding Comparison Values, North Area RI Soil Samples] and 9 [Detected Concentrations Exceeding Comparison Values, RI Wetland Sediment Samples]), and the relatively low solubilities of those PCOCs that are present (*i.e.*, primarily, pesticides, PAHs, and/or metals). Although these classes of PCOCs are relatively persistent, the lack of contaminant migration within the wetland areas north of the Site, as indicated by the limited extent of PCOCs in wetland sediments beyond the Site area (Figure 9), supports the expectation of low sediment and dissolved load transport of PCOCs within the North Area.

Within the South Area, some PSAs, such as the sand blasting area, are exposed and PCOCs are present above screening levels at the surface of the ground. Exposed soils, consisting primarily of fill material, and indications of surface soil erosion are present within this area. Local areas of soil erosion and subsequent sediment deposition are apparent at the northern ends of the barge slips in Lots 21 and 22 (Figure 2 – Site Map). The PAHs detected in sediment samples from the end of the barge slips, particularly sample IWSE03 (Figure 10 – Detected Concentrations Exceeding Comparison Values, Intracoastal Waterway RI Sediment Samples), compared to the PAHs detected in nearby surface soil samples, for example sample SA3SB17 (Figure 11 – Detected Concentrations Exceeding Comparison Values, South Area Phase 1 Perimeter RI Soil Samples), support the inference of surface soil erosion into the ends of the barge slips. However, the general absence of PAHs or other PCOCs in other areas of the barge slips toward the Intracoastal Waterway suggests limited migration of PCOC-containing sediments.

12.3.2.3 Ground Water Transport Pathways

Ground water in Zones A and B within the North Area near the former surface impoundments contains elevated concentrations of a number of VOCs, including 1,1,1-

trichloroethane (1,1,1-TCA); 1,1-dichloroethene (1,1-DCE); 1,2,3-trichloropropane (1,2,3-TCP); 1,2-dichloroethane (1,2-DCA); benzene; cis-1,2-dichloroethene (cis-1,2-DCE); methylene chloride; tetrachloroethene (PCE); trichloroethene (TCE); and vinyl chloride (VC). These VOCs are collectively referred to as the primary ground water COIs. In addition to dissolved phase concentrations of these COIs, visible NAPL was observed within the soil matrix at the base of Zone A in the soil cores for monitoring wells ND3MW02 and ND3MW29, and at the base of Zone B in the soil core for monitoring well NE3MW30B, although NAPL has not been observed in ground water samples in these or any other Site monitoring wells. Additionally, no NAPL sheens were observed in these wells. Soil samples from the cores at ND3MW29 and NE3MW30 contained many of these same primary ground water COIs along with other compounds, including PAHs. The former surface impoundments are believed to be the source of the NAPL and dissolved primary ground water COI concentrations. Approximately 100 cubic yards of sludge within the impoundments that reportedly could not be excavated during impoundment closure in 1982 was solidified with soil and left in place.

The ground water pathway for potential transport of primary ground water COIs or other PCOCs is lateral migration within Zones A and B and vertical migration, possibly as NAPL in very localized areas, or in dissolved form from Zone A to Zone B in areas where the clay separating Zone A and Zone B pinches out or is of minimal thickness. Vertical migration to deeper water-bearing zones below Zone B is effectively precluded by the thick and low vertical hydraulic conductivity (7×10^{-9} cm/sec) clay layer below Zone B.

12.3.2.4 Contaminant Plume Stability

The stability of dissolved phase plumes for the primary ground water COIs in Zone A was evaluated through plots of the lateral extents of the ten VOCs identified in Section 12.3.2.3 (Ground Water Transport Pathways) for three ground water sampling periods between July 2006 and June 2008 (Figures 12 through 21). In these figures, the lateral extent of each COI was defined by the concentration contour corresponding to its respective Zone A extent evaluation comparison value from Table 3 (Ground Water Extent Evaluation Comparison Values). The lateral extent of a COI based on samples collected during the period between July 2006 and June 2007 is shown in blue on these figures. These samples correspond to the initial sample collected from a well, or the sole sample collected from a temporary piezometer, and thus varies by the date the well/piezometer was installed. The lateral extent of a COI based on samples collected in November 2007 (the second sampling event of each well, as applicable) is shown in green on these figures, and the lateral extent based on samples collected in June 2008 (the third sampling event of each well, as applicable) is shown in red. For most of the ten primary ground water COIs, the overall plume area for the third sampling event was similar or, in some cases such as methylene chloride, significantly smaller than the overall plume area for the initial sampling event.

Sections of the projected southern boundaries of the plume areas for 1,1,1-TCA (Figure 12 – Lateral Extent of 1,1,1-TCA Concentrations in Zone A, July 2006 Through June 2008), cis-1,2-DCE (Figure 17 – Lateral Extent of CIS-1,2-DCE Concentrations in Zone A, July 2006 Through June 2008), PCE (Figure 19 – Lateral Extent of PCE Concentrations in Zone A, July 2006 Through June 2008), and TCE (Figure 20 – Lateral Extent of TCE Concentrations in Zone A, July 2006 Through June 2008) show some limited expansion between the three sampling events. This indication is primarily due to concentration increases of those COIs in samples from well ND3MW02. Similar increasing concentrations of 1,1,1-TCA, cis-1,2-DCE, PCE, and TCE were also observed in ground water samples from ND3MW29, located at the southwestern corner of the former surface impoundments. Visible indications of NAPL were observed in the soil cores from the borings for wells ND3MW02 and ND3MW29 at depths within the screened intervals of those two wells. As shown on Table 4 (Detected Concentrations in SBMW29-01 and SBMW30-01 Soil Samples), 1,1,1-TCA, PCE and TCE were the COIs present at the highest concentrations in soil samples from those core intervals and thus those COIs appear to be among the primary components of the NAPL observed in the cores. The dissolution of residual NAPL containing 1,1,1-TCA, PCE and TCE within the local screened areas of ND3MW02 and ND3MW29 is a likely explanation for why concentrations of those COIs, and the degradation product cis-1,2-DCE, in samples collected from those wells were not observed to decrease over time as was observed in most of the other monitoring wells in the vicinity. Thus, despite a few exceptions for some COIs in the local areas around ND2MW29 and ND3MW02 in the plume interior where NAPL was observed in the soil core, the overall time-series plume area plots for the primary ground water COIs as shown in Figures 12 through 21 clearly exhibit generally stable or declining trends.

The Zone A potentiometric gradient has typically been relatively flat with local variability indicated at individual well/piezometer locations. A ground water divide was often observed within the plume areas, typically south of the former surface impoundments (Figures 22 through 27). The ground water flow direction was usually toward the west or northwest in the area north of the divide, and usually toward the south or southwest in the area south of the divide. For several of the primary ground water COIs (*e.g.*, 1,1,1-TCA as shown in Figure 12 [Lateral Extent of 1,1,1-TCA Concentrations in Zone A, July 2006 Through June 2008]), some expansion of the southern plume boundary toward the south or southeast may be inferred; however, a contraction or reduction in the northern plume boundary, which would also be in an apparent downgradient direction from the center of the plume, is indicated.

12.3.3 Exposure Points and Exposure Routes

The following sections of the ROD discuss the possible human and ecological exposure points and routes that are addressed by the Baseline Human Health Risk Assessment, Screening Level Ecological Risk Assessment, and Baseline Ecological Risk Assessment for the Site.

12.3.3.1 Human Exposures

In the South Area, PCOCs could have been released from historical PSAs to the soil and then migrated to ground water via leaching through the soil column, and to surface water in the Intracoastal Waterway via overland surface runoff. It should be noted, however, that there is very little topographic slope at the Site and indications of soil erosion are not apparent. Once in surface water, some PCOCs would tend to stay dissolved in the water whereas others would tend to partition to sediment. Volatilization and dust generation could have caused some PCOCs in soil to migrate within the Site or off-site. Exposure to on-site receptors could also potentially occur through direct contact with the soil. Based on PCOC (*i.e.*, lead) data for surface soil samples collected on Lots 19 and 20 directly west of the Site and the evaluation conducted in the BHHRA, it does not appear that significant entrainment and subsequent deposition of soil particles through dust generation and transport has occurred at the Site or at off-site locations. Once in ground water, VOCs could potentially migrate with the ground water and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

At the North Area, PCOCs were potentially released from historical PSAs to the soil and/or may have migrated to ground water. PCOCs may have also migrated from soil to surface water and sediments in the nearby wetlands area via overland surface runoff. Like the South Area, the minimal topographic slope in the North Area likely has not resulted in significant overland surface runoff. Fugitive dust generation was considered a potentially significant transport pathway for PCOC migration on-site and evaluated quantitatively in the Baseline Human Health Risk Assessment for the on-site receptors although this pathway was eliminated during the screening process for the off-site residential receptor. Once in ground water, VOCs may migrate with the ground water and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

12.3.3.2 Ecological Exposures

Potential routes of migration for ecological pathways in the terrestrial and aquatic ecosystems are depicted in Figures 5 (Conceptual Site Model – Terrestrial Ecosystem) and 6 (Conceptual Site Model – Aquatic Ecosystem), respectively. Based on Site data, potential ecological exposure pathways were identified as either incomplete, not viable, potentially complete, or posing no unacceptable risk based on the results of the Screening Level Ecological Risk Assessment. Potentially complete ecological exposure pathways are indicated with a solid square in the far right columns of Figures 5 and 6.

Potential terrestrial ecosystem receptors (Figure 5 – Conceptual Site Model, Terrestrial Ecosystem) include vegetation, detritivores, invertebrates, herbivores, omnivores, and carnivores. Potentially complete terrestrial exposure pathways involve contaminant releases from PSAs to soil, potential suspension and/or deposition, or erosion/runoff, followed by: (1) direct contact/soil ingestion by all potential receptors; (2) gill uptake by potential detritivore and invertebrate receptors; and (3) food ingestion by all potential non-vegetation receptors. The potential risks associated with the complete pathways were quantified in the Screening Level Ecological Risk Assessment, and further evaluated in the Baseline Ecological Risk Assessment.

Potential aquatic ecosystem receptors (Figure 6 – Conceptual Site Model, Aquatic Ecosystem) include benthos and epibenthos, zooplankton, fish and shellfish, and vertebrate carnivores. Potentially complete aquatic exposure pathways involve: (1) direct contact by all receptors; (2) gill uptake by applicable receptors; (3) food ingestion by all non-vegetation receptors; and (4) media (*e.g.*, surface water and sediment) by applicable receptors. The potential risks associated with these pathways were quantified in the Screening Level Ecological Risk Assessment and further evaluated in the Baseline Ecological Risk Assessment.

12.3.4 Potentially Exposed Populations

The Baseline Human Health Risk Assessment, Screening Level Ecological Risk Assessment, and Baseline Ecological Risk Assessment for the Site were focused on the current and/or future populations likely to be exposed to each of the potentially contaminated media at the Site. This approach ensures that the range of risks over various population subgroups will be characterized for potential activities and land and/or water uses.

12.3.4.1 Human Health Receptors

The potentially exposed populations evaluated in the Baseline Human Health Risk Assessment for the on-site and off-site areas of the North Area of the Site were:

- Off-site Resident: Inhalation of ambient air.

- Future On-site Industrial/Commercial Worker: Inhalation of ambient/indoor air, skin contact with and accidental ingestion of water, skin contact with and/or ingestion of sediments, direct skin contact with and ingestion of soil**.**

- Future On-site Construction Worker: Inhalation of ambient air, inhalation of vapors close to source while excavation, skin contact with and accidental ingestion of water, skin contact with and/or ingestion of sediments, direct skin contact with and ingestion of soil.

- Potential Current Youth Trespasser: Inhalation of ambient air, skin contact with and accidental ingestion of water, inhalation of vapors close to source, direct skin contact and/or ingestion of sediment, and direct skin contact as well as ingestion of soil.

- Contact Recreational User: A contact recreation scenario was assessed for surface water and sediment in the wetlands and ponds of the North Area to represent a hypothetical receptor who occasionally contacts these media while wading, birding, or participating in other recreational activities.

The receptors evaluated for the on- and off-site areas of the South Area of the Site were:

- Offsite Resident: Inhalation of ambient air, ingestion of fish, skin contact with and accidental ingestion of water, inhalation of vapors from ground water, skin contact with and/or ingestion of sediments.

- Future On-site Industrial/Commercial Worker: Inhalation of ambient/indoor air, direct skin contact with and ingestion of soil.

- Future On-site Construction Worker: Inhalation of ambient/indoor air, direct skin contact with and ingestion of soil.

- Potential Current Youth Trespasser: Inhalation of ambient air and direct skin contact as well as ingestion of soil.

- Contact Recreational User: A contact recreation scenario was assessed for surface water and sediment in the wetlands and ponds of the South Area to represent a hypothetical receptor who occasionally contacts these media while wading, birding, or participating in other recreational activities.

12.3.4.2 Ecological Receptors

Because the Screening Level Ecological Risk Assessment concluded that there were no upper trophic level risks and threatened and endangered species have not been observed at the Site, the Baseline Ecological Risk Assessment focused on potential impacts to receptors where adverse risk was predicted in the SLERA (*i.e.*, soil/sediment invertebrates and water column receptors).

12.4 Soils

The Site consists of approximately 40 acres along the north bank of the Intracoastal Waterway and is located within the 100-year coastal floodplain (FEMA, 2009). The alluvium at the Site consists of clay, silt, sand and gravel, with abundant organics within the soil horizon. The South Area includes approximately 20 acres of upland created from material dredged from the Intracoastal Waterway. Most of the North Area is considered wetlands although there are some upland areas, also created from dredged spoil material. The fill and spoil material consists of dredged material that was used to raise the surface of the land above the alluvium and barrier island deposits. This spoil material is highly variable with mixed mud, silt, sand, and shell.

12.5 Site Geology/Hydrogeology and Ground Water Classification

The geology and hydrogeology of the Site was studied to develop the CSM and to provide an understanding of the potential exposure pathways at the Site. The ground water was classified to determine the applicable ground water response objectives and types of response measures.

12.5.1 Site Geology

The surficial geology of the Gulf Coast Plain is fairly complex due to the variety of active geologic environments occurring in the region. Active geologic environments in the coastal zone include fluvial-deltaic, barrier-strandplain-chenier, bay-estuary-lagoon systems, eolian systems, marsh-swamp systems, and offshore systems. The Site is located in an area of a Modern-Holocene Colorado-Brazos River Delta system and a Modern marsh system and the surficial geology of the site is predominantly Quaternary alluvium with some “fill and spoil” from the construction of the Intracoastal Waterway. The geologic units occurring below the Quaternary alluvium are, from youngest to oldest, the Beaumont Clay, Lissie Formation, Goliad Formation, Fleming Formation, Oakville Sandstone, and the Catahoula Tuff or Sandstone.

12.5.2 Site Hydrogeology

Ground water Remedial Investigation activities included evaluations of the possible presence of NAPL, including both light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL), in Site monitoring wells. The three uppermost water-bearing units at the Site, which are designated from shallowest to deepest as Zones A, B, and C, respectively, were evaluated as part of the Site ground water investigation.

12.5.2.1 Zone A Ground Water-Bearing Unit

Zone A is the uppermost water-bearing unit at the Site. It is generally first encountered at a depth of 5.0 to 15.0 ft bgs, with an average depth of approximately 10.0 ft bgs. Zone A ranges in thickness from approximately 2.0 to 10.0 ft, with an average thickness of approximately 8.0 ft.

12.5.2.1.1 Zone A Lithology and Distribution of Transmissive Zones

Zone A consists of a heterogeneous mixture of poorly graded sand to silty sandy clay with typically a high percentage of fine-grained material. The heterogeneous and fine-grained nature of Zone A is typical of overbank flood deposits. Zone A was present in all the borings drilled at the Site. As shown on Figure 28 (Zone A Thickness Map), Zone A is generally thicker in the central areas of the Site. With a couple of exceptions (SA4PZ07 and SJ1MW15), Zone A appears to become thinner towards the west and east portions of the Site. The structure contour map of the base of Zone A (Figure 29 – Structure Contour Map - Base of Zone A) depicts a highly variable surface with elevations ranging from approximately -3 feet MSL to -20 feet MSL. The highest elevations of the base of Zone A generally occur in the southwest and northeast areas of the Site, while the lowest elevations are to the south and west.

Across the site, Zone A is overlain by a firm, medium- to high-plasticity clay (Unit I on Figure 30 [Idealized Site Hydrostratigraphic Column]). The thickness and intrinsically low hydraulic conductivity of the clay serves to hydrostatically isolate Zone A from the surface. Although the land surface at the Site, particularly the North Area, is often inundated with surface water due to extreme high tides, from storm surge and/or flooding of Oyster Creek, water levels within Zone A have not been observed to respond to these events. Rather, it appears that the clayey surficial soils cause the perching of surface water that inundates the Site. Some sandier zones and areas of coarser-grained artificial fill material are present above the Unit I clay overlying Zone A. These zones are generally limited to the near surface, are discontinuous and primarily occur within the South Area or the former parking lot in the North Area.

12.5.2.1.2 Zone A Ground Water Movement and Flow Conditions

Ground water in Zone A predominantly occurs under confined conditions as indicated by water level elevations in Zone A monitoring wells/piezometers above the top of the unit. The Zone A potentiometric surface was evaluated through six water-level measurement events performed between October 2006 and June 2008 (Figures 22 through 27). Overall, the Zone A potentiometric surface is relatively flat. The potentiometric maps generally show a ground water divide near the center of the Site (typically in the North Area). The ground water flow direction is typically towards the west or northwest in the area north of the divide, and generally flow is to the south and southwest to the south of the divide.

The Zone A hydraulic gradient is highly variable across the Site, ranging from 0.02 feet/feet (ft/ft) immediately to the northwest of the ground water divide to less than 0.001 ft/ft in the South Area. The gradient magnitude surrounding the ground water divide is typically about 0.005 ft/ft.

Slug tests were performed on three Zone A monitoring wells to estimate the hydraulic conductivity of this zone. Estimated Zone A hydraulic conductivities ranged from 4×10^{-5} cm/sec to 8×10^{-5} cm/sec, which are within the range of typical values for a silt to silty sand. Based on these estimated hydraulic conductivities and a ground water gradient of 0.001 ft/ft to 0.02 ft/ft, the specific discharge of Zone A ranges from about 4×10^{-8} cm/sec to 2×10^{-6} cm/sec (0.04 ft/year to 2 ft/year). Dividing this range by a typical porosity of 0.4 for silt yields an average linear ground water velocity of 0.1 ft/year to 5.0 ft/year.

Based on the Intracoastal Waterway channel design depth of 12 ft, and the Zone A base elevations of approximately -12 ft MSL to -17 ft MSL in soil borings drilled near the shoreline (see Figure 29 [Structure Contour Map - Base of Zone A]), it is likely that Zone A intersects the Intracoastal Waterway in areas adjacent to the Site. In the areas where this intersection occurs, the ground water/surface water discharge relationship likely shows both short- and long-term variations depending on Zone A potentiometric levels and the tidal stage of the waterway. Regardless of the specific recharge/discharge condition at a given point in time, the net flux between Zone A and the Intracoastal Waterway is likely to be relatively low given: (1) the low hydraulic conductivity of Zone A, (2) the limited thickness of the unit adjacent to the shoreline (less than 12 feet as indicated on Figure 28 [Zone A Thickness Map]), and (3) the relatively low magnitude of tidal range fluctuations (mean tidal range of 1.41 ft) within the waterway.

12.5.2.2 Zone B Ground Water-Bearing Unit

Zone B is first encountered at a depth of 15.0 to 33.0 ft bgs. The average depth to the top of Zone B was approximately 19.0 ft bgs. Zone B is separated from Zone A by a medium- to high-plasticity clay that ranged in thickness from approximately 2.0 to 7.0 ft. Where present, Zone B sands ranged in thickness from as little as 1.0 ft to as much as approximately 20.0 ft, with an average thickness of approximately 11.0 ft.

12.5.2.2.1 Zone B Lithology and Distribution of Transmissive Zones

Zone B is separated from Zone A by a medium- to high-plasticity clay (Unit II on Figure 30 [Idealized Site Hydrostratigraphic Column]) that typically ranges in thickness from about 2.0 to 7.0 ft. This confining unit pinches out in the southeastern part of the Site, as indicated by its absence at monitoring well SL8MW17.

Zone B is a silty to well-graded sand. As shown on Figure 31 (Zone B Thickness Map), Zone B is thickest near monitoring well NE4MW31B and thins to the northwest and west where it eventually pinches out. Zone B was not encountered in boring NC2B23B in the western part of the North Area and was very thin (0.2 ft thick) in boring OB26B north of the Site. Similarly, the Zone B base elevation is highest in the western part of the Site (Figure 32 [Structure Contour Map – Base of Zone B]) where it is at its thinnest. The base of Zone B generally dips to the east, with the lowest base elevation observed at Well NE4MW32C where the greatest thickness of the zone was also encountered.

12.5.2.2.2 Zone B Ground Water Movement and Flow Conditions

Ground water in Zone B also occurs under confined conditions. The Zone B potentiometric surface was evaluated through five water-level measurement events performed between June 2007 and July 2008 (Figures 33 through 37). Data from the first water-level measurement events (June 6 and September 6, 2007 as shown on Figures 33 and 34, respectively), indicate an easterly ground water flow direction. The hydraulic gradient for these events was approximately 0.0006 ft/ft to 0.0009 ft/ft. Data from the three subsequent events

(November 7, 2007; December 3, 2007; and July 30, 2008, as shown on Figures 35, 36, and 37, respectively) showed a general flow direction to the northwest. The hydraulic gradient for these events ranged from approximately 0.001 ft/ft to 0.006 ft/ft.

Slug tests were performed on three Zone B monitoring wells to estimate the hydraulic conductivity of this zone. Estimated hydraulic conductivities ranged from 2 x 10^{-5} cm/sec to 5 x 10^{-4} cm/sec, which is typical of a silty sand. Based on an overall ground water gradient of 0.003 ft/ft and a hydraulic conductivity of 1 x 10^{-4} cm/sec, the average specific discharge for Zone B is estimated at about 3 x 10^{-7} cm/sec (0.3 ft/year). Dividing this average by a typical porosity of 0.4 for sand yields an average linear ground water velocity of 0.8 ft/year.

The vertical hydraulic gradient between Zones A and B was evaluated through a comparison of water-elevations at three sets of paired wells screened in these units during five monitoring events. In all but two instances, an upward gradient from Zone B to Zone A was indicated. The magnitude of these upward gradients ranged from 0.02 ft/ft to 0.15 ft/ft. The two observed downward gradients (both for the ND4MW03/ ND4MW24B pair) were 0.02 ft/ft.

12.5.2.3 Zone C Ground Water-Bearing Unit

Zone C consisted of a thin, less than 0.5 ft thick, shell layer at a depth of approximately 73.0 ft bgs within a high plasticity clay unit. Approximately 25.0 ft or more of clay to silty clay separate Zone C from Zone B, where Zone B is present.

12.5.2.3.1 Zone C Lithology and Distribution of Transmissive Zones

Zone C consists of a thin (approximate thickness of one foot or less) shell hash layer within this thick clay unit. One ground water monitoring well, NE4MW32C was installed into Zone C, which occurred at a depth of about 73.0 ft bgs and was less than 0.5 feet thick at the well location. Five cone penetrometer test (CPT) borings and associated push-in piezometers were also installed in Zone C. The CPT logs indicated that this zone, which is distinguishable by a decrease in the CPT sleeve friction-to-tip resistance ratio, appeared to be present at all five CPT locations.

Approximately 25.0 to 50.0 ft of the Unit III clay separates Zone C from the overlying Zone B. The vertical hydraulic conductivity of this clay is extremely low, ranging from 5.7 x 10^{-9} to 6.6 x 10^{-9} cm/sec. Due to the significant thickness (greater than 25.0 ft) and the low hydraulic conductivity of the Unit III clay separating Zones B and C, ground water communication/flow between these zones is highly unlikely. Additionally, the vertical hydraulic conductivity of a Unit III clay sample collected from a boring at a depth of approximately 80.0 ft was measured at 1.6 x 10^{-8} cm/sec.

12.5.2.3.2 Zone C Ground Water Movement and Flow Conditions

Figures 38 through 41 depict the Zone C potentiometric surface for four water-level measurement events between June 2008 and January 2009. The four potentiometric surface maps suggest a generally northwest ground water gradient within Zone C. A ground water divide in the general area of NE4MW32C appears to be present during the September 29, 2008, and January 13, 2009, events (Figures 40 and 41, respectively). The magnitude of the Zone C hydraulic gradient appears relatively uniform across the North Area, typically in the range of 0.005 ft/ft to 0.008 ft/ft.

Vertical hydraulic gradients between Zones B and C were evaluated through comparison of water-level elevations of three pairs of wells screened in these two units for two monitoring events. A downward gradient from Zone B to Zone C was indicated in all well pairs for all of the monitoring events. The magnitude of these downward gradients ranged from 0.13 ft/ft to 0.21 ft/ft. Even though a downward vertical hydraulic gradient exists from Zone B to Zone C, there is likely little to no hydraulic communication between the two units. More than 25.0 feet of high plasticity clay with a very low vertical hydraulic conductivity of 6×10^{-9} to 7×10^{-9} cm/sec separates these two zones.

12.5.3 Site Ground Water Classification

Ground water within Zone A has high natural salinity. Total Dissolved Solids (TDS) concentrations in Zone A ground water samples ranged from 29,900 mg/L to 39,800 mg/L with an average value of 34,850 mg/L. According to the EPA’s ground water classification system, water with a TDS concentration greater than 10,000 mg/L is defined as non-potable. Likewise, the TCEQ, at 30 Texas Administrative Code 350.52, defines ground water with a TDS concentration that is greater than 10,000 mg/L as Class 3 ground water, which is not considered usable as drinking water. The EPA’s secondary drinking water standard for TDS is 500 mg/L. Due to its natural salinity, Zone A has not been historically used as a water supply source.

Ground water within Zone B also has high natural salinity as indicated by a TDS concentration of 34,500 mg/L in a sample from a monitoring well. Like Zone A, ground water in Zone B has not been used as a drinking water source in the vicinity of the Site due to the high natural salinity and is not considered potable.

Although lower than for Zones A and B, ground water in Zone C also has high natural salinity. The TDS concentration of a sample from a monitoring well was 24,600 mg/L, above Class 3 and potability criteria.

12.6 Nature and Extent of Contamination

The objective of the Remedial Investigation (RI, PBW 2011b) was to define the nature and extent of Site contamination so that informed decisions can be made regarding the Site. The extent of contamination is documented by using analytical data of sufficient quality to support the risk assessment and the selection of remedial alternatives. The nature and extent of COIs in Site environmental media were investigated during the RI through the collection of Site and background Intracoastal Waterway sediment and surface water samples, fish tissue samples, South and North Area soil samples, background and off-site soil samples, former surface impoundment cap soil borings, wetland sediment and surface water samples, ground water samples, and pond sediment and surface water samples. For the Site's ground water investigation, monitoring wells and temporary and permanent piezometers were installed throughout the Site during the RI.

12.6.1 North Area Soils

The nature and extent of contamination in North Area soils was investigated through the collection of: (1) Phase 1 samples from the 0 to 0.5 ft and 1 to 2 foot depth intervals at 14 grid-based locations; (2) a Phase 2 sample from the 4 to 5 foot depth interval at one of these 14 locations (ND3SB04); (3) Phase 2 samples from the 0 to 0.5 foot and 1.5 to 2.0 foot depth intervals at locations SB-201, SB-202, and SB-203 where scrap metal was observed at the ground surface; and (4) Phase 2 samples from varying depths at locations SB-204, SB-205, and SB-206 in the area where subsurface debris (*e.g.*, a section of rope) was observed in the auger cuttings from a monitoring well boring. Soil samples for laboratory analyses were collected from SB-204, SB-205, and SB-206 at depth intervals generally corresponding to one foot immediately above observed subsurface debris, one foot immediately below the debris, and within the approximate center of the observed debris layer, except at SB-205 where a sample was not collected below the debris as described below. North Area soil sample locations are shown on Figure 42 (North Area RI Soil Sample Locations).

Since the physical extent of soil in the North Area is bound by the surrounding wetland areas (where wetland sediment samples were collected and evaluated), the lateral extent of potential soil contamination in the North Area was effectively determined by the lateral extent of soil. The vertical extent of contamination in North Area soils was evaluated through a comparison of soil data to the extent evaluation comparison values listed in Table 5 (Extent Evaluation Comparison Values – Eastern and Vertical Extent in Soil). Table 6 (Detected RI Soil Sample Concentrations Exceeding Extent Evaluation Comparison Values – Vertical Extent of North Area) and Figure 7 (Detected Concentrations Exceeding Vertical Comparison Values – North Area RI Soils Samples) list detected soil concentrations in the North Area soil samples that exceed the soil extent evaluation comparison values listed in Table 5. In most cases where an exceedance was noted, a deeper soil sample with no comparison value exceedances defined the vertical extent of contamination. At boring locations ND3SB04 and SB-206, exceedances were noted in the deepest sample collected (4.0 to 5.0 foot and 5.0 to 6.0 foot depth intervals, respectively); however, in accordance with Work Plan provisions that soil samples need not be collected from depths below either: (1) the water table; or (2) the surface soil depth at the sample location as defined in 30 TAC 350.4(a) (88) (*i.e.*, 5.0 ft), deeper sampling was not performed.

At boring SB-205, debris was observed from approximately 3.0 to 6.0 ft bgs. Given the depth of the debris relative to the saturated zone (saturated conditions were observed at a depth of approximately 4.0 to 5.0 ft), it was decided not attempt to collect a sample below the debris at this location. Thus, sampling was not performed below the 3.0 to 4.0 foot depth interval sample although iron and lead concentrations in this sample exceeded their respective comparison values (Table 6 – Detected RI Soil Sample Concentrations Exceeding Extent Evaluation Comparison Values - Vertical Extent of North Area). The laboratory was unable to analyze the 3.0 to 4.0 foot depth interval sample (the debris interval sample) at boring location SB-205 for organic analytes due to solidification of the sample extracts during the concentration step of the analyses. Such solidification is consistent with olfactory and visual indications of naphthalene in this sample at the time of collection. As indicated by the absence of naphthalene exceedances in nearby SB-204 and SB-206 samples (Table 6), and the lack of visual and olfactory indications of naphthalene observed during the drilling of those borings, the area containing naphthalene in buried debris or adjacent soils appears limited to the vicinity of SB-205.

Borings SB-201 through SB-203 were drilled to evaluate the possible presence of subsurface debris in this vicinity where scrap metal materials were present on the ground surface. As shown in Table 6, the only metals concentrations above their respective vertical extent comparison criteria in these borings were iron and lead in the 0 to 0.5 foot depth sample from SB-202. These metals were not present at concentrations greater than their respective vertical extent comparison values in the 1.5 to 2.0 foot depth sample from this location. Benzo(a)pyrene (BaP) was reported above its vertical extent comparison value in the 1.5 to 2.0 foot sample from SB-203, but was not detected in the 0 to 0.5 foot sample at this location. Based on the SB-201 through SB-203 concentration data and visual observations from these borings, which did not indicate the presence of significant subsurface debris, no further investigation of this area was performed.

12.6.2 South Area Soils

Soil samples collected to determine the nature and extent of contamination in the South Area soils included: (1) Phase 1 samples from the 0 to 0.5 ft and 1 to 2 foot depth intervals from 85 grid-based locations; (2) Phase 2 samples from the 4 to 5 foot depth interval from 15 of these locations; and (3) Phase 2 samples from various depth intervals at seven locations on the adjacent former commercial marina parcel to the west, which is also referred to as “Lot 20” (Figure 43 – South Area Soil Investigation Program Sample Locations). Analytical data from these samples were used to evaluate the extent of contamination through a comparison to preliminary screening levels (PSVs) for soil, subject to a comparison to background concentrations, as determined from Site-specific background samples or Texas-specific background concentrations provided in 30 TAC 350.51(m). This evaluation included the following:

(1) Western Extent of Contamination – Phase 1 analytical data for the 0 to 0.5 foot and 1 to 2 foot depth interval samples from the westernmost grid column of the South Area sample grid (Grid Column A as shown on Figure 43 [South Area Soil Investigation Program Sample Locations]) were initially used to evaluate the western extent of contamination at the Site. Based on this comparison, the locations and analyses for Phase 2 samples collected from Lot 20 were determined. The Lot 20 data were then used to evaluate the western extent of contamination overall.

(2) Eastern Extent of Contamination – Phase 1 analytical data for the 0 to 0.5 foot and 1 to 2 foot depth interval samples from the easternmost grid column of the South Area sample grid (Grid Column L as shown on Figure 43) were used to evaluate the eastern extent of contamination in the South Area.

(3) Vertical Extent of Contamination – Phase 1 analytical data for the 1 to 2 foot depth interval samples from all locations were initially used to evaluate the vertical extent of contamination at the Site. Based on this comparison, the locations and analyses for Phase 2 samples collected from the 4 to 5 foot depth interval were determined. These deeper samples were then used to evaluate the vertical extent of contamination.

The southern extent of potential soil contamination is defined by the Intracoastal Waterway since it bounds the physical extent of soil on the southern end of the South Area. The northern extent of potential soil contamination in the South Area is similarly defined by Marlin Avenue, whose construction occurred prior to industrial operations in the South Area, and the North Area of the Site, which primarily consists of wetland areas and the former surface impoundments.

Site-specific background soil data were obtained from ten surface soil samples collected approximately 2,000 feet east of the Site near the east end of Marlin Avenue (Figure 1 – Site Location Map). These background samples were analyzed for pesticides, SVOCs, and selected metals (antimony, arsenic, barium, chromium, copper, lead, lithium, manganese, mercury, molybdenum, and zinc). Pesticides, SVOCs, antimony and cadmium were not detected at sufficient frequencies in background soil samples to warrant the development of Site-specific background values for these COIs. Site-specific background values were developed for all other metals for which background soil samples were analyzed.

12.6.2.1 Western Extent of Soil Contamination Evaluation

The western extent of soil contamination in the South Area was evaluated based on analytical data for the 0 to 0.5 foot and 1 to 2 foot depth interval samples from the westernmost grid column of the South Area sample grid (Grid Column A on Figure 43 [South Area Soil Investigation Program Sample Locations]). As shown in Table 7 (Extent Evaluation Comparison Values – Western Extent of South Area Soils), the comparison values for each COI are the higher of its PSV or background value (where applicable). The background values listed in Table 7 are the Texas-specific background concentrations provided in 30 TAC 350.51(m) and the Site-specific background values.

Detected soil concentrations in western perimeter samples (*i.e.*, Grid Column A locations) that exceed the Table 7 comparison values are listed in Table 8 (Detected RI Soil Sample Concentrations Exceeding Extent Evaluation Comparison Values – Western Extent of South Area) and are shown on Figure 11 (Detected Concentrations Exceeding Comparison Values – South Area Phase 1 Perimeter RI Soil Samples). Based on these data, samples were collected from seven locations from Lot 20, the former commercial marina parcel to the west of the Site. Several exceedances were noted in these Lot 20 samples ("Phase 2 samples" as listed in Table 8) and shown on Figure 11. A review of the Lot 20 and Grid Column A data suggests the presence of an off-site contaminant source in the vicinity of sample locations L20SB06 and L20SB07, where concentrations of several COIs (particularly lead and zinc) were significantly higher than concentrations observed in adjacent South Area samples. As shown on Figure 11, location L20SB07 is at the edge of a dry dock facility associated with the former commercial marina. Regardless of the source of the exceedances at locations L20SB04 through L20SB07, the western extent of potential soil contamination is bound by the former commercial marina boat slip area to the west which is the physical extent of soil west of these samples. The BaP concentration in the 0 to 0.5 foot depth interval sample at L20SB01 is also believed to be associated with an off-site source since no BaP exceedances were observed in multiple depth samples from sample locations L20SB02 and L20SB03, which are between the South Area and L20SB01. The lead exceedance, estimated concentration of 19 mg/kg, at L20SB01 is only slightly above the Site-specific background lead value of 17.9 mg/kg and is also believed to be associated with an off-site source based on a lead concentration of 462 mg/kg in a nearby surface sample (L20SS04 shown on Figure 44 [Lead Concentrations in Lot 19-20 Surface Soil Samples]) collected as part of the residential surface soil investigation described below. Based on this evaluation, it is concluded that the western extent of soil contamination in the South Area has been defined.

12.6.2.2 Eastern Extent of Soil Contamination Evaluation

The eastern extent of soil contamination in the South Area was evaluated based on analytical data for the 0 to 0.5 foot and 1 to 2 foot depth interval samples from the easternmost grid column of the South Area sample grid (Grid Column L on Figure 43 [South Area Soil Investigation Program Sample Locations]). Ecological PSVs were not considered for the eastern extent evaluation because the property east of the South Area is an operating industrial facility with no appreciable ecological habitat. Thus, the comparison values in Table 5 (Extent Evaluation Comparison Values – Eastern and Vertical Extent in Soil) were used for this evaluation. The comparison values for each COI in Table 5 are the higher of its PSV or background value (where applicable). No detected concentrations in the eastern perimeter samples (*i.e.*, Grid Column L locations) exceeded the Table 5 comparison values. Based on this evaluation, it is concluded that the eastern extent of soil contamination in the South Area has been defined.

12.6.2.3 Vertical Extent of Soil Contamination Evaluation

Ecological PSVs were not considered for the vertical extent evaluation because Site soil conditions suggest that there is limited potential for significant biological activity below a depth of two feet and representative Site ecological receptors typically do not burrow below this depth. Based on these considerations, human health PSVs (Table 5 – Extent Evaluation Comparison Values – Eastern and Vertical Extent in Soil) were used, with background, for the vertical extent of soil contamination evaluation.

Table 9 (Detected RI Soil Sample Concentrations Exceeding Extent Evaluation Comparison Values – Vertical Extent of South Area) lists the detected soil concentrations in the Phase 1 samples that exceed the Table 5 comparison values. Based on these data, deeper soil samples were collected from the 4 to 5 foot depth interval at 15 locations and analyzed as listed in Table 10 (South Area Phase 2 RI Deep Soil Sample Data). No comparison value exceedances were detected, thus the vertical extent of COIs in South Area soils is limited to depths less than 4 feet, except for a sample collected from a depth of 4.5 feet during the removal action.

12.6.3 Nature and Extent of Residential Surface Soil Investigation

The investigation for the nature and extent of residential surface soil contamination included the collection of surface soil samples for chemical analysis from the 0 to 1 inch depth interval at 27 specified locations on off-site Lots 19 and 20 (Figure 45 – Residential Surface Soil Investigation Program Sample Locations). The analytical suite for these samples was determined through an evaluation of data for 0 to 1 inch and 0 to 0.5 foot depth interval samples from on-site Lots 21, 22 and 23. Site lot designations are shown on Figure 2 (Site Map). Based on this evaluation, the 27 surface soil samples collected from off-site Lots 19 and 20 were analyzed for lead.

Lead concentrations in the Lot 19/20 surface soil samples are listed in Table 11 (Lot 19/20 Soil Sample Lead Concentrations) and plotted on Figure 44 (Lead Concentrations in Lot 19-20 Surface Soil Samples). The lead PSVs for the direct contact exposure pathways are the EPA Region 6 human health media-specific screening level for soil of 400 mg/kg, and the TCEQ ${}^{Tot}Soil_{Comb}$ PCL of 500 mg/kg, which includes inhalation, ingestion and dermal pathways. Thus, a lead concentration of 400 mg/kg was used as the comparison value for assessing whether further surface soil investigation beyond Lots 19 and 20 was necessary.

The sole Lot 19/20 surface soil sample with a lead concentration greater than 400 mg/kg was sample L20SS04 that showed a concentration of 462 mg/kg. As shown on Figure 44 (Lead Concentrations in Lot 19-20 Surface Soil Samples), this sample was collected adjacent to a concrete slab (and the location of a former building) associated with former commercial marina operations on Lot 20. This lead concentration is believed to be indicative of a local source associated with the former marina rather than a source at the Site. As shown on Figure 44, lead concentrations in Lot 20 surface soil samples (0 to 1 inch depth interval) collected between L20SS04 and the Site (*i.e.*, samples L20SS05 and L20SS06) were below or near the lead background concentration of 17.9 mg/kg, and thus far below the L20SS04 result or similarly elevated lead concentrations that would be expected if the Site were a source of elevated lead to this area. Regardless of the source of the lead concentration at L20SS04, the lead concentrations in surface soil samples between L20SS04 and Snapper Lane to the west (as indicated by the data for samples L19SS01, L19SS02, L19SS08, L19SS09, L19SS15, and L20SS01 as shown on Figure 44) were all far below the 400 mg/kg comparison value, thus precluding the need for further residential soil investigation sampling. Lead concentrations in the seven westernmost surface soil sample locations near Snapper Lane (samples L19SS01 through L19SS07 as shown on Figure 44) were all below or near the background lead concentration of 17.9 mg/kg, further demonstrating the absence of impacts to soil in this area.

12.6.4 Intracoastal Waterway Sediments

The nature and extent of contamination in Intracoastal Waterway sediments was investigated through the collection and analysis of samples from the 0 to 0.5 ft depth interval at 17 locations adjacent to the Site (Figure 46 – Intracoastal Waterway RI Site Sample Locations) and nine background locations (Figure 47 – Intracoastal Waterway RI Background Sample Locations). As noted previously, samples could not be collected from two additional Site locations (IWSE35 and IWSE36 on Figure 46) due to insufficient sediment thickness for an adequate sample.

Chemical concentrations in perimeter Site sediment samples were compared to PSVs and background data on an individual sample basis. Only certain metals were detected at a sufficient frequency in the background sediment samples to warrant development of a background value. The PSVs and background values considered for evaluating the lateral extent of COIs in Intracoastal Waterway sediment are listed in Table 12 (Extent Evaluation Comparison Values – Intracoastal Waterway Sediments). The extent evaluation comparison values listed in this table represent the higher of either the PSV or background value (where applicable) for each COI.

As shown in Table 13 (Detected Intracoastal Waterway RI Sediment Sample Concentrations Exceeding Extent Evaluation Comparison Values) and on Figure 10 (Detected Concentrations Exceeding Comparison Values – Intracoastal Waterway RI Sediment Samples), one or more COIs (4,4’-DDT and certain PAHs, including some carcinogenic PAHs) were detected at concentrations exceeding their respective comparison values at five Site sediment sample locations. Approximately two-thirds of these exceedances have a “J” data qualifier indicating an estimated concentration, typically between the sample detection limit and the sample quantitation limit. All five exceedance locations were within or on the perimeter of the barge slip areas. The lateral extent of COIs in sediment at these locations is defined by location IWSE34 to the west, where 4,4'-DDT (the sole exceedance at location IWSE01) was not detected, locations IWSE35 and IWSE36 to the south, where as noted previously, a sufficient sediment thickness for sample collection was not present, and locations IWSE06, IWSE09, and IWSE10 to the east, where no exceedances were observed.

Contaminated ground water from the North Area of the Site does not discharge to the sediments of the Intracoastal Waterway adjacent to the South Area of the Site. The lateral extent of Site ground water containing COIs at concentrations above extent evaluation criteria is generally limited to a localized area within the North Area, roughly over the southern half of the former surface impoundments area and a similarly sized area immediately to the south. The EPA does not believe that the impacted ground water will reach the Intracoastal Waterway sediments given the limited extent of contaminant migration observed during the 27 to 38 years since operation and closure of the former surface impoundments and the low ground water velocity at the Site.

12.6.5 Intracoastal Waterway Surface Water

Intracoastal Waterway surface water was investigated through the collection and analysis of four composite samples adjacent to the Site (Figure 46 – Intracoastal Waterway RI Site Sample Locations) and four composite background samples (Figure 47 – Intracoastal Waterway RI Background Sample Locations). Based on the absence of any COIs exceeding PSVs in Intracoastal Waterway surface water samples adjacent to the Site, background surface water values were not calculated for this comparison. Thus, the extent evaluation comparison values listed in Table 14 (Surface Water Extent Evaluation Comparison Values) reflect the lowest updated PSVs. It should be noted that aldrin and dissolved silver concentrations in samples from all four background sample locations (IWSW30 through IWSW33) exceeded their respective extent evaluation comparison values. Concentrations of 4,4'-dichlorodiphenyldichloroethane (DDD) and 4,4'-DDT in the sample from background location IWSW33 also exceeded their respective extent evaluation comparison values.

Contaminated ground water from the North Area of the Site does not discharge to the surface water of the Intracoastal Waterway adjacent to the South Area of the Site. The lateral extent of Site ground water containing COIs at concentrations above extent evaluation criteria is generally limited to a localized area within the North Area, roughly over the southern half of the former surface impoundments area and a similarly sized area immediately to the south. The EPA does not believe that the impacted ground water will reach the Intracoastal Waterway surface water given the limited extent of contaminant migration observed during the 27 to 38 years since operation and closure of the former surface impoundments and the low ground water velocity at the Site.

12.6.6 Wetland Sediments

The nature and extent of contamination in wetland sediments was investigated through the collection of: (1) samples from the 0 to 0.5 foot depth interval at 17 Phase 1 locations; (2) samples from the 1 to 2 foot depth interval at 10 of these locations, where saturated conditions were not encountered at depths less than 2 feet; (3) samples from the 0 to 0.5 foot depth interval at 17 additional judgmental locations; (4) samples from the 0 to 0.5 foot depth interval at ten perimeter locations; and (5) samples from the 0 to 0.5 foot depth interval at two other locations. These 46 wetland sediment sample locations are shown on Figure 48 (RI Wetland and Pond Sample Locations). Wetland sediment sample analytical data were used to evaluate the lateral extent of contamination through a comparison to sediment PSVs, subject to a comparison to background concentrations. Given the similar composition and condition of the surface soils collected from within the approved background soil area to the wetland sediments in the North Area, the Site-specific background values determined from those soil samples were used to represent background wetland sediment concentrations for the purposes of evaluating the lateral extent of contamination. As shown in Table 15 (Wetland and Pond Sediment Extent Evaluation Comparison Values), the comparison value for each COI is the higher of its PSV or background value (where applicable). The background values listed in Table 15 are the Site-specific background values.

Detected COI concentrations in wetland sediment samples that exceed the Table 15 comparison values are listed in Table 16 (Detected RI Wetland Sediment Sample Concentrations Exceeding Extent Evaluation Comparison Values) and plotted on Figure 9 (Detected Concentrations Exceeding Comparison Values – RI Wetland Sediment Samples). As shown on this figure, extent evaluation comparison values were not exceeded in any of the outermost wetland sediment samples. Therefore, it is concluded that the lateral extent of contamination in wetland sediment to the west, north, south, and east has been identified. The physical extent of wetland sediments, and thus potential contamination in wetland sediments, is bound by Marlin Avenue and South Area soils to the south.

12.6.7 Wetland Surface Water

The nature and extent of contamination in wetland surface water was investigated through the collection of samples at four locations shown on Figure 48 (RI Wetland and Pond Sample Locations). Detected COI concentrations in these four surface water samples (2WSW1, 2WSW2, 2WSW3, and 2WSW6) were evaluated relative to the surface water extent evaluation comparison values listed in Table 14 (Surface Water Extent Evaluation Comparison Values). The concentrations listed in Table 17 (Detected RI Wetland Surface Water Sample Concentrations Exceeding Extent Evaluation Comparison Values) exceeded their respective extent evaluation comparison values. These exceedances are also plotted on Figure 49 (Detected Concentrations Exceeding Comparison Values – RI Wetland Surface Water Samples).

As shown on Figure 49 and Table 17, wetland surface water comparison value exceedances were limited to acrolein, copper, mercury, and manganese. The lateral extent of the copper and manganese exceedances noted in Sample 2WSW6 is effectively bound by the extent of surface water within the small area of ponded water south of the former surface impoundments where this sample was collected. This area was completely dry in June 2008. The southern extent of copper and mercury in samples 2WSW1 and 2WSW2 north of the Site is defined by sample 2WSW3 where no exceedances were observed. The northern, western, and eastern extent of the acrolein, copper and mercury in sample 2WSW1 is effectively bound by the physical extent of perennial standing water in this area (*i.e.*, standing water is not perennially present in these directions). Based on this conclusion, no further investigation of wetland surface water was performed.

12.6.8 Ponds Sediment

The nature and extent of contamination in pond sediments was investigated through the collection of samples from the 0 to 0.5 foot depth interval at five locations within the Fresh Water Pond and three locations within the Small Pond as shown on Figure 48 (RI Wetland and Pond Sample Locations). Detected chemical concentrations in these samples were evaluated relative to the sediment extent evaluation comparison values listed in Table 15 (Wetland and Pond Sediment Extent Evaluation Comparison Values). The concentrations listed in Table 18 (Detected RI Pond Sediment Sample Concentrations Exceeding Extent Evaluation Comparison Values) exceeded their respective comparison values. These exceedances are also plotted on Figure 50 (Detected Concentrations Exceeding Comparison Values – RI Pond Sediment Samples). As shown thereon, all exceedances were associated with the Small Pond, where zinc concentrations in all three samples exceeded the comparison value and the 4,4'-DDT concentration in the southernmost sample exceeded the comparison value. The lateral extent of these sediment exceedances are bound by the limited physical extent of the pond.

12.6.9 Ponds Surface Water

The nature and extent of contamination in pond surface water was investigated through the collection of samples from three locations within the Fresh Water Pond and three locations within the Small Pond as shown on Figure 48 (RI Wetland and Pond Sample Locations). Detected chemical concentrations in these samples were evaluated relative to the surface water extent evaluation comparison values listed in Table 14 (Surface Water Extent Evaluation Comparison Values). The concentrations listed in Table 19 (Detected RI Pond Surface Water Sample Concentrations Exceeding Extent Evaluation Comparison Values) exceeded their respective comparison values. As shown on Figure 51 (Detected Concentrations Exceeding Comparison Values – RI Pond Surface Water Samples), the ponds surface water exceedances were limited to total arsenic (two Fresh Water Pond samples), total or dissolved thallium (all samples except for one location in the Fresh Water Pond), total and dissolved manganese (Small

Pond samples), and dissolved silver (all samples). The lateral extents of these surface water exceedances are bound by the limited extents of the ponds.

12.6.10 Ground Water

The three uppermost water-bearing units at the Site, which are designated from shallowest to deepest, as Zones A, B, and C, respectively, were evaluated as part of the Site ground water investigation. An evaluation of the possible presence of LNAPL and DNAPL in Site monitoring wells was performed as part of ground water investigation activities using an interface probe and/or bailer. Visible NAPL was observed within the soil matrix at the base of Zone A in the soil cores for monitoring wells ND3MW02 and ND3MW29, and at the base of Zone B in the soil core for monitoring well NE3MW30B. Soil samples were collected from these cores at ND3MW29 and NE3MW30 (Samples SBMW29-01 and SBMW30-1) respectively and analyzed for VOCs, SVOCs, and pesticides. COIs detected in these soil samples are listed in Table 4 (Detected Concentrations in SBMW29-01 and SBMW30-01 Soil Samples). As shown on Table 4, 1,1,1-TCA, PCE and TCE were the COIs present at the highest concentrations in these soil samples and thus appear to be among the primary components of the NAPL observed in the cores. Monitoring well evaluations (*i.e.*, NAPL thickness measurements using an interface probe and/or bailer) did not encounter NAPL, or NAPL sheens, in these or any other Site monitoring wells.

12.6.10.1 Zone A

The extent of contamination in Zone A was evaluated through the collection and analysis of samples from 24 monitoring wells and 8 temporary piezometers. Samples from the initial 17 Zone A monitoring wells (MW01 through MW17) and 8 piezometers (PZ01 through PZ08) were analyzed for the complete suite of ground water analytes. The analytical data from these samples were used to evaluate the extent of ground water contamination at the Site, and assess the need for additional ground water investigation activities. This evaluation entailed a comparison to PSVs on an individual sample basis. The PSVs used for this evaluation were TCEQ PCLs for Class 3 ground water (*i.e.*, ground water from low-yielding units or with TDS concentrations greater than 10,000 mg/L), PCLs for volatilization of COIs from ground water to ambient air, and TCEQ ecological benchmark values for surface water, conservatively assuming ground water discharge to surface water. The extent evaluation comparison values are listed in Table 3 (Ground Water Extent Evaluation Comparison Values).

Detected COI concentrations in Zone A ground water samples that exceeded Table 3 extent evaluation comparison values are listed in Table 20 (Detected Zone A Ground Water Concentrations Exceeding Extent Evaluation Comparison Values). Exceedances were predominantly for VOCs, specifically the following ten compounds:

- Trichloroethane (1,1,1-TCA);

- 1,1-dichloroethene (1,1-DCE);
- 1,2,3-trichloropropane (1,2,3-TCP);
- 1,2-dichloroethane (1,2-DCA);
- Benzene;
- Cis-1,2-dichloroethene (Cis-1,2-DCE);
- Methylene chloride;
- Tetrachloroethene (PCE);
- Trichloroethene (TCE); and
- Vinyl chloride (VC)

For several of these compounds, ground water concentrations in a few wells exceeded 1% of the compound's solubility limit, which is often used as an indicator for the possible presence of NAPL. This is primarily true for samples from monitoring wells ND3MW02 and ND3MW29, where, as noted previously, visible indications of NAPL were observed within the soil matrix in soil core samples. At ND3MW29, for example, the maximum 1,1,1-TCA ground water concentration of 234.0 mg/L is approximately 5% of its solubility (4,400 mg/L), the maximum PCE ground water concentration of 12.9 mg/L is approximately 9% of its solubility (150 mg/L), and the maximum TCE concentration of 135.0 mg/L is approximately 12% of its solubility (1,100 mg/L). As indicated previously, NAPL was observed in the soil cores from monitoring wells ND3MW02 and ND3MW29; however, no NAPL was observed in the ground water samples for the monitoring well evaluations for the NAPL described in this section of the ROD.

Isoconcentration maps for the ten primary ground water COIs listed above (Figures 52 through 61) were used to project the lateral extent of contamination within Zone A. Multiple samples were collected from some Zone A monitoring wells as indicated in Table 20; in those cases, the COI concentration data for the most recent sample from that well were plotted on Figures 52 through 61.

The outermost contour lines on Figures 52 through 61 reflect the extent evaluation comparison value for the specific VOC shown on each of the figures. As shown on the figures, the concentration distribution is fairly consistent between VOCs, with highest concentrations typically observed near the southern corner of the former surface impoundments. The lateral extent of contamination, indicated by the outermost contour line, was limited to the North Area, in all cases except for benzene and vinyl chloride where exceedances were noted in the sole sample collected from temporary piezometer ND1PZ03 located immediately north of the Site property boundary. Typically the lateral extent of VOCs was limited to the southern half of the former surface impoundments area and a similarly sized area immediately to the south.

Several SVOCs (*i.e.*, primarily anthracene, naphthalene, phenanthrene, and pyrene) and pesticides (*i.e.*, primarily endosulfan II, endosulfan sulfate, 4,4'-DDE, Dieldrin, gamma-BHC, and heptachlor epoxide) were occasionally detected in Zone A ground water samples at concentrations exceeding extent evaluation comparison values (Table 20). These exceedances were either: (1) not confirmed by a second sample collected at that location (*e.g.*, the endosulfan sulfate and heptachlor epoxide exceedances in the August 2, 2006 sample from SJ1MW15 were not confirmed in a subsequent sample collected from this well on June 4, 2007); (2) not confirmed by a sample from a monitoring well subsequently installed adjacent to a temporary piezometer location (*e.g.*, the endosulfan II exceedance at NB4PZ01 was not confirmed by the sample from monitoring well NB4MW18); or (3) bounded by samples from downgradient monitoring wells that did not show exceedances of that specific COI (*e.g.*, gamma-BHC exceedances at SF5MW10 were bounded by samples from SE6MW09, SF6MW11, and SG2MW13).

As indicated in Table 20, chromium, nickel, and silver concentrations exceeded extent evaluation comparison values in a number of Zone A ground water samples. In all cases, these concentrations exceeded TCEQ ecological benchmark values for surface water ecological surface water criteria, but were far below TCEQ Class 3 ground water PCLs (Table 3 – Ground Water Extent Evaluation Comparison Values). As such, these exceedances are solely attributable to the conservative assumption of direct and undiluted discharge of Site ground water to surface water. Furthermore, the ecological benchmark values are intended to apply to dissolved concentrations in surface water rather than the total concentrations represented by the ground water data. Considering the presence of a significant amount of fine-grained material in Zone A soils (*i.e.*, silt or clay), it is highly unlikely that the chromium, silver, and nickel concentrations detected in ground water samples reflect actual dissolved concentrations in ground water that could be theoretically discharged to surface water. Even if the observed total chromium, nickel, and silver concentrations did reflect dissolved concentrations discharging to surface water, the resultant mass flux would be extremely low and would be readily diluted at the point of discharge. Thus, these ecological benchmarks for dissolved metals concentrations in surface water are not considered applicable to total metals concentrations in ground water samples. As a result, the chromium, nickel and silver ground water exceedances relative to ecological surface water criteria data were not used to define the lateral extent of contamination in Zone A.

12.6.10.2 Zone B

The extent of contamination in Zone B was evaluated through the collection and analysis of samples from five monitoring wells. Monitoring wells were not installed in two additional proposed Zone B soil borings (NC2B23B and OB26B) because Zone B was not present at those locations. COI concentrations in the five Zone B ground water samples are listed in Table 21 (Zone B Ground Water Concentrations). Consistent with extent evaluation procedures specified in the Work Plan for ground water-bearing units that are unlikely to discharge to surface water or sediments, the extent evaluation comparison values listed for Zone B in Table 21 do not consider ecological PSVs. As indicated in this table, the only detected concentrations exceeding extent evaluation comparison values were seven VOCs in the sample collected from well NE3MW30B, southeast of the former surface impoundments. Ground water concentrations of several COIs in well NE3MW30B exceeded the 1% compound solubility limit threshold indicating the possible presence of NAPL. For example, the 1,1,1-TCA ground water concentration of 64.0 mg/L is approximately 1.5% of its solubility (4,400 mg/L), the PCE ground water concentration of 23.8 mg/L is approximately 16% of its solubility (150.0 mg/L), and the TCE concentration of 170.0 mg/L is approximately 15% of its solubility (1,100 mg/L). These ground water data support the observation of visible NAPL within the soil matrix at the base of Zone B in the soil core for NE3MW30B; however, no NAPL was observed in the ground water samples from this well. The lateral extent of contamination in Zone B is limited to NE3MW30B since there were no exceedances in samples from the other Zone B monitoring wells.

12.6.10.3 Zone C

The extent of contamination in Zone C was evaluated through the collection and analysis of samples from one ground water monitoring well (NE4MW32C) and five CPT piezometers. COI concentrations in the ground water samples collected from this well and these piezometers are listed in Table 22 (Zone C Ground Water Concentrations). As for Zone B, the extent evaluation comparison values listed for Zone C in Table 22 do not consider ecological PSVs. As indicated in this table, the only concentrations exceeding extent evaluation comparison values were 1,2,3-TCP; PCE; and TCE in the initial sample collected from monitoring well NE4MW32C; and 1,2,3-TCP in a second sample collected from this well. No exceedances were noted in two subsequent samples collected from NE4MW32C, nor were any exceedances indicated in samples from any of the five CPT piezometers. Based on the absence of any exceedances in the five Zone C piezometers, and the lack of confirmed exceedances in NE4MW32C, it is concluded that the vertical extent of contamination in Site ground water has been defined.

13.0 CURRENT AND POTENTIAL FUTURE LAND/GROUND WATER USES

The following sections of the ROD discuss the current and reasonably anticipated future land uses, and current and potential ground water uses at the Site. These sections also discuss the basis for future use assumptions.

13.1 Current and Potential Future Land Uses

The land use for the North Area and South Area is currently classified by the City of Freeport Zoning Code.

The land use for the North Area is currently zoned as “M-2, Heavy Manufacturing.” This classification allows for manufacturing and industrial activities. The North Area consists of undeveloped land, a former parking area, and the closed surface impoundments.

The South Area is currently unused but it is anticipated that the South Area will be used for commercial/industrial purposes in the future. The South Area is zoned as “W-3, Waterfront

Heavy." This classification provides for port, harbor, or marine-related activities including the storage, transport, and handling and manufacturing of goods, materials, and cargoes related to marine activities. The South Area was developed for industrial uses with improvements including multiple structures, a dry dock, two barge slips, a sand blasting area, and a former AST Tank Farm.

Restrictive covenants limiting types of land uses, construction, and ground water use have been filed for various parcels of the Site. Restrictive covenants prohibiting any land use other than commercial or industrial and prohibiting ground water use have been filed for all parcels within both the North and South Areas. Additional restrictions requiring any building design to preclude indoor vapor intrusion have been filed for Lots 55, 56, and 57 in the North Area. A further restriction requiring EPA and TCEQ notification prior to any building construction has also been filed for Lots 55, 56, and 57.

13.2 Current and Potential Future Ground Water Uses

Ground water in Zones A and B is characterized by TDS concentrations of approximately 30,000 mg/L or more. These TDS concentrations are approximately triple the 10,000 mg/L level used by the EPA to define water as non-potable and by the TCEQ to identify Class 3 ground water (*i.e.*, ground water not considered useable as drinking water). Due to naturally high salinity, Zones A and B, as well as underlying ground water-bearing zones within the upper approximately 200.0 ft of the subsurface, have not been used as a water supply source, and it is not expected that these water-bearing zones will be used as a potable source of drinking water in the future. Section 12.5.3 (Site Ground Water Classification), of this ROD, further describes the EPA's and TCEQ's ground water classification systems.

14.0 SUMMARY OF SITE RISKS

The following sections of the ROD provide a summary of the Site's human health and ecological risks. The Baseline Human Health Risk Assessment (BHHRA, PBW 2010b), Baseline Ecological Risk Assessment (BERA, URS 2011), and Screening Level Ecological Risk Assessment (SLERA, PBW 2010a) Reports for the Site estimate the probability and magnitude of potential adverse human health and environmental effects from exposure to contaminants associated with the Site. Under the NCP, 40 CFR §300.430, the role of the BHHRA is to address the risks associated with a site in the absence of any remedial action or control, including institutional controls. The baseline assessment is essentially an evaluation of the no-action alterative (See 55 Fed. Reg. 8666, 8710-8711 [March 8, 1990]). The BHHRA also provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action.

BHHRAs and SLERAs are an integral part of the RI and Feasibility Study process. A BHHRA estimates the current and possible future risks if no action were taken to clean up a site.

The EPA's Superfund risk assessors determine how threatening a hazardous waste site is to human health and the environment. They seek to determine a safe level for each potentially dangerous contaminant present (*e.g.*, a level at which ill health effects are unlikely and the probability of cancer is very small). Living near a Superfund site doesn't automatically place a person at risk, that depends on the chemicals present and the ways people are exposed to them. An ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors. A stressor is any physical, chemical, or biological entity that can induce an adverse ecological response. Adverse responses can range from sub-lethal chronic effects in individual organisms to a loss of ecosystem function.

14.1 Summary of the Baseline Human Health Risk Assessment

The BHHRA was conducted according to the EPA's guidance document titled "Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A," (EPA/540/1-89/002, Office of Emergency and Remedial Response) (EPA 1989). The BHHRA estimates what risks the Site poses to human health if no action were taken. It provides the basis for taking action at this Site, and identifies the contaminants and exposure pathways that need to be addressed by the remedial action presented in this ROD. This BHHRA followed a four step process:

Step 1. Data Collection and Evaluation (Identification of Constituents of Potential Concern [COPCs]),

Step 2. Exposure Assessment,

Step 3. Toxicity Assessment, and

Step 4. Risk Characterization.

In Step 1, the concentrations of contaminants found at the Site as well as past scientific studies on the effects these contaminants have had on people, or animals when human studies are unavailable, were evaluated. Comparisons between site-specific concentrations and concentrations reported in past studies allow a determination of which contaminants are most likely to pose the greatest threat to human health. In Step 2, the risk assessment considers the different ways that people might be exposed to the contaminants identified in Step 1, the concentrations that people might be exposed to, and the potential frequency and duration of exposure. Using this information, a "reasonable maximum exposure" (RME) scenario is calculated, which portrays the highest level of human exposure that could reasonably be expected to occur. In Step 3, the risk assessment uses the information from Step 2 combined with information on the toxicity of each chemical to assess potential health risks. The risk assessment considers two types of risk: cancer risk and non-cancer risk. In Step 4, the risk assessment determines whether site risks are great enough to cause health problems for people living at or near the Site.

The EPA used an exposure point concentration (EPC) for each COC and the RME scenario to estimate risk. The EPC was the lesser of the maximum detected concentration and the 95% upper confidence limit (95% UCL) of the arithmetic mean concentration of the COCs in soil or ground water. A 95% UCL is a statistically-derived value based on sample data within an exposure area. The RME scenario is the maximum exposure that is reasonably expected to occur at the Site and is based on “upper bound” and “central tendency” estimates. The use of multiple conservative exposure factors makes the RME scenario protective of potential exposures.

Human health risks are determined by evaluating known chemical exposure limits and actual chemical concentrations found at a site during field sampling activities. The actual contaminant concentrations are compared to the exposure concentrations known to have an adverse impact. In the risk assessment, carcinogenic and non-carcinogenic health risks are calculated. The risk calculation uses conservative assumptions that weigh in favor of protecting human health. The results may be used to make decisions regarding the necessity and extent of remediation, to develop site-specific cleanup levels, and to help select appropriate remedial technologies.

14.1.1 Identification of Potential Chemicals of Concern

The EPA’s human health risk assessment guidance (EPA 1989) recommends considering several steps to eliminate compounds from further evaluation and, as such, this section describes the process used to reduce the list of chemicals evaluated in the BHHRA. Compounds were eliminated from further consideration if: 1) they were detected infrequently in a given media (*i.e.*, in less than five percent of the samples); 2) they were measured at similar concentrations in blank samples; 3) they were measured at similar concentrations in background samples; or 4) they were detected at a high concentration (*i.e.*, above one tenth of the screening value). If a compound was detected in less than five percent of the samples, the compound was eliminated from further evaluation for that media. This step was only considered in media where twenty or more samples were collected and if that compound was not present in another media. The data for soil, ground water, surface water, and sediment are summarized in Tables 23 through 37. These tables show the frequency of detection, minimum, maximum, and average concentration for each COI. The 95% UCL of the mean concentration was calculated from these data.

14.1.1.1 Concentration-Toxicity Screen

A “concentration-toxicity screen” step, as recommended by the EPA’s human health risk assessment guidance (EPA 1989), was conducted to limit the number of chemicals that were included in a quantitative risk assessment while also ensuring that all chemicals that might contribute significantly to the overall risk were addressed. The screening values used were $1/10^{th}$

of the human health criteria, which were the lower of the EPA's or TCEQ's values as presented in the Nature and Extent Data Report (NEDR, PBW 2009) for soil, surface water, and sediment. Because there are no readily available screening levels appropriate for the complete ground water pathway at the Site, all chemicals of interest for the ground water medium were quantitatively evaluated in the BHHRA. A similar screen was conducted for media collected at the background areas, but this was done merely for comparative purposes. Risks associated with background concentrations were not calculated in the BHHRA.

Exposure and risk calculations were not estimated for the surface water pathway in the Intracoastal Waterway and wetlands area because none of the measured maximum COI concentrations exceeded 1/10th of their respective TCEQ's contact recreation PCL. These PCLs were developed for a child exposure scenario for non-carcinogenic compounds, and an age-adjusted scenario for carcinogenic compounds. The PCL is based on incidental ingestion and dermal contact of surface water while swimming for three hours and 39 times per year. It is believed that this is a conservative estimate for the Intracoastal Waterway, surface water north of Marlin Avenue, and the ponds north of Marlin Avenue since none of these surface water bodies are very favorable for swimming and true exposure is likely to be much less than the scenario described by TRRP's contact recreation PCL. All surface water concentrations were well below 1/10th of the PCL for the Intracoastal Waterway and wetlands area surface water. Maximum measured concentrations of arsenic and thallium in the pond samples exceeded 1/10th of their respective PCL but did not exceed the PCL and, therefore, neither were retained for further evaluation. Although TCEQ does not provide a PCL for iron, one was calculated using the contact recreation assumptions (TCEQ 2006). Measured concentrations of iron in surface water were well below the calculated contact recreation PCL of 2,800 mg/L. Therefore, it was concluded that chemical concentrations of PCOCs in surface water samples from the Intracoastal Waterway near the Site, surface water in the North Area wetlands, and surface water in the North Area ponds do not pose an unacceptable human health risk and chemical concentrations in these media were not evaluated further in the BHHRA.

14.1.1.2 Comparison to the Background Areas

To help provide an understanding of what COIs and concentrations are considered to be Site-related, a background evaluation was conducted that included: 1) soil samples from ten off-site locations, 2) sediment samples from nine off-site locations in the Intracoastal Waterway, and 3) surface water samples within four off-site "zones" in the Intracoastal Waterway. This information was used to characterize Site conditions in the NEDR (PBW 2009).

The soil background data were compared to soil from the South and North Areas of the Site, as well as sediments from the North wetland and the North Area ponds. As described in the NEDR (PBW 2009), based on similarities in composition and condition between background soil and sediments of the North wetlands area, this comparison was appropriate. Sediment and surface water data for the Intracoastal Waterway samples were compared to sediment and surface water data collected in the Intracoastal Waterway background location.

Comparisons between Site sampling data and Site-specific background data were conducted for all inorganic compounds measured regardless if they exceeded the concentration-toxicity screen. Table 38 (Background Comparisons) summarizes the results of the testing and indicates whether the Site data were found to be statistically different than the background data. Background ground water data were not collected as part of the RI. Therefore, all COIs detected in Zone A ground water, as shown in the tables for the South Area and North Area, were evaluated quantitatively in the BHHRA.

14.1.2 Exposure Assessment

The exposure assessment estimates the extent of human contact with PCOCs by characterizing potentially exposed populations (*i.e.*, receptors), identifying actual or potential routes of exposure, and quantifying the intake (or dose) of human exposure. The exposure assessment also identifies possible exposure pathways that are appropriate for each potential receptor and exposure scenario and considers the source of contamination and fate and transport properties of the compound and surrounding environment. An exposure pathway typically includes the following elements:

- A source of contaminant and mechanism of contaminant release,
- An environmental retention or transport medium (*e.g.*, air, ground water, etc.),
- A point of contact with the medium (*i.e.*, receptor or potentially exposed population), and
- A route of human intake (*e.g.*, inhalation, ingestion, etc.).

Each of these elements must generally be present for an exposure pathway to be complete, although it is not necessary that environmental transport occurs when assessing exposure from direct contact. Exposure was evaluated for both current and potential future receptors to allow for evaluation of long-term risk management options.

14.1.3 Potential Exposure Pathway Evaluation

The identification of potentially exposed populations, or receptors, possibly at risk from exposure to PCOCs at the Site is dependent on current and future land uses. The Site consists of approximately 40 acres within the 100-year coastal floodplain along the north bank of the Intracoastal Waterway between Oyster Creek to the east and the Old Brazos River Channel to the west. Approximately 78 people live within the one square mile area surrounding the Site. Approximately 3,392 people live within 50 square miles of the Site. There are no schools, nursing homes, or other sensitive subpopulations within a mile of the Site. Residential areas are located south of Marlin Avenue, approximately 300 feet west of the Site and 1,000 feet east of the Site.

14.1.3.1 Land use and Pathway Evaluation

Historically, the South Area of the Site was used as a barge cleaning and maintenance facility. The Site currently is unused but it is anticipated that the South Area will be used for commercial/industrial purposes in the future. The South Area includes approximately 20 acres of upland that was created from dredged material from the Intracoastal Waterway. To the west of and directly adjacent to the Site is an unused lot that was formerly a commercial marina. West of that lot, beyond a second vacant lot, is a residential development with access to the Intracoastal Waterway. An active commercial operation is located east of the South Area.

The North Area of the Site contains former surface impoundments which were certified closed in 1982 and is, for the most part, unused. Some of the North Area is upland created from dredge spoil, but most of this area is considered wetlands and the wetlands area has never consistently been used. According to the National Wetlands Inventory map for the Freeport Quadrangle, the wetlands on the north of the Site are estuarine, intertidal, emergent, persistent, and irregularly flooded. The upland area of the North Area has been used as a parking lot. Future land use at the North Area is limited given that much of it is considered wetlands and most of the upland part of the North Area consists of the closed former surface impoundments.

14.1.3.2 Ground Water Use and Pathway Evaluation

Because of high total dissolved solids in Zones A, B, and C ground water at the Site, the ground water ingestion and use pathway is incomplete for these three units. Also, as noted previously, restrictive covenants prohibiting ground water use have been filed for the Site. Based on Site potentiometric and analytical data presented in the NEDR (PBW 2009), impacted ground water does not affect surface water at the Site. Thus, the only complete exposure pathway is the volatilization to indoor and outdoor air pathway in areas above impacted ground water. A restrictive covenant requiring any building design to preclude vapor intrusion has been filed for Lots 55, 56, and 57 where VOC concentrations were measured in relatively high concentrations in Zone A ground water. Nevertheless, this pathway was conservatively evaluated in the BHHRA.

14.1.3.3 Surface Water Use and Pathway Evaluation

The Intracoastal Waterway supports barge traffic and other activities. It is one of the main arteries for shipping goods from Freeport’s deep-water port to destinations along the Texas Coast and beyond. Fishing boats also use the Intracoastal Waterway to gain access to the fishing grounds in the Gulf of Mexico and the shorelines, tributaries, and marshes of many of Texas' bays. The area near the Site is regularly dredged. The nearby residential areas have canal access to the Intracoastal Waterway.

Contaminated ground water does not discharge to surface water at the Site. However, surface water data were collected for the Intracoastal Waterway, as well as surface waters contained in the wetlands and ponds on the North Area to evaluate the potential for contaminants in surface soils to be released to surface water via overland surface runoff. A contact recreation scenario was included in the risk assessment to evaluate risks associated with occasional swimming and wading in surface water of the Intracoastal Waterway, and surface waters on the North Area. Based on the screening evaluation, the surface water pathway was eliminated from further consideration since it does not pose an adverse human health risk.

14.1.3.4 Fish and Shellfish Resources and Pathway Evaluation

Fishing and crabbing are reported to occur in waters of the Intracoastal Waterway in the general vicinity of the Site. Based on the analytical results for the Intracoastal Waterway sediment samples, fish tissue samples were collected from four Site zones and one background area within the Intracoastal Waterway. Red drum (*Sciaenops ocellatus*) (6 samples), spotted seatrout (*Cynoscion nebulosus*) (9 samples), southern flounder (*Paralichthys lethostigma*) (9 samples), and blue crab (*Callinectes sapidus*) (9 samples) samples were collected from the Site for laboratory analysis. Samples of these species were also collected from the background area and were archived.

The Site fish tissue samples (*i.e.*, fillet samples for finfish and edible tissue for crabs) were analyzed for 12 COIs, based on Intracoastal Waterway sediment data. The only COIs with concentrations measured above sample detection limits in any of the 33 samples were silver (detected in four samples), benzo(b)fluoranthene (detected in two samples), and 4,4'-DDE (detected in two samples). The fish tissue data were used to calculate potential risks associated with exposure to Site COIs via the fish ingestion pathway to recreational anglers fishing at the Site, or their families. This risk assessment concluded that the fish ingestion pathway does not pose a human health threat (PBW 2007).

Shellfish harvesting is banned by the Texas Department of Health Services, Seafood Safety Division, in all waterbodies from an area about two miles east of the Site, to well beyond the Brazos River inlet, about 7 miles west of the Site. The ban has been enacted because of poor conditions and water quality. It should be noted, however, that risk from shellfish consumption harvested from the area if allowed would most likely not pose a human health risk, since exposure would be similar if not the same as for the fish and crab ingestion pathway.

For the reasons described above, the fish/shellfish pathways were not evaluated further in this risk assessment.

14.1.4 Potentially Exposed Populations

Based on current and reasonable future land use, potentially exposed populations for the South Area include: 1) future commercial/industrial workers, and 2) future construction workers at the Site. A youth trespasser was also evaluated since, although the South Area perimeter is fenced, this area could still be accessed by a trespasser via the Intracoastal Waterway. Soil is the primary media of concern for these receptors. A future indoor air exposure pathway was evaluated for the commercial/industrial worker since VOCs were detected in Zone A ground water. Additionally, a contact recreation scenario was assessed for surface water and sediment in the Intracoastal Waterway to represent a hypothetical person who occasionally contacts these media while swimming, wading, or participating in other recreational activities. Potential impacts from fugitive dust generation and VOC emissions, and subsequent exposure to nearby residents were also considered in the BHHRA.

Based on current and reasonable future land use, potentially exposed populations for the North Area include: 1) future commercial/industrial workers, and 2) future construction workers at the Site. A youth trespasser was also evaluated since this area is not fenced. Soil is the primary media of concern for these receptors. A future indoor air exposure pathway was evaluated for the commercial and industrial worker since VOCs were detected in Zone A ground water. Additionally, a contact recreation scenario was assessed for surface water and sediment in the wetlands and ponds of the North Area to represent a hypothetical receptor who occasionally contacts these media while wading, birding, or participating in other recreational activities. Given the frequently saturated nature of the wetlands sediment and the abundant vegetation on the uplands portion of the North Area, fugitive dust generation and VOC emissions, and off-site impacts were not considered.

While exposure might occur at the background locations, exposure and potential risks for background areas were not evaluated in the BHHRA.

14.1.5 Conceptual Site Models and Potentially Complete Exposure Pathways

The CSM identifies exposure pathways for potentially complete pathways at the Site and describes the process or mechanism by which human receptors may reasonably come into contact with Site-related constituents. A CSM was developed to focus the data collection activities of the RI so that analytical data could support a risk-based analysis. Figures 4 (Human Health Conceptual Site Model - South Area) and 4 (Human Health Conceptual Site Model - North Area) of the BHHRA provide revised CSMs for the South and North Areas, respectively, which were refined to reflect current information about the Site. These revised CSMs were used to develop the quantitative exposure assessment of the BHHRA. Section 12.3 (Conceptual Site Model), of this ROD, provides detailed descriptions of the human health and ecological CSMs for the Site.

At the South Area, PCOCs were potentially released from historical Potential Source Areas (PSAs) to the soil and may have migrated to ground water via leaching through the soil column, and to surface water in the Intracoastal Waterway via overland surface runoff. Once in surface water, some compounds tend to stay dissolved in the water whereas some tend to partition to sediment. Volatilization and fugitive dust generation may have caused PCOCs in soil to migrate within the Site or off-site. Exposure to on-site receptors may also occur directly from contact to the soil. However, based on PCOC data for surface soil samples collected on Lots 19 and 20 directly west of the Site, it does not appear that significant entrainment and subsequent deposition of particulates occurred at the Site or at off-site locations. Once in ground water, VOCs may migrate with the ground water and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

At the North Area, PCOCs were potentially released from historical PSAs to the soil and/or may have migrated to ground water. PCOCs may have also migrated from soil to surface water and sediments in the nearby wetlands area via overland surface runoff. Because of the high moisture content and the vegetated nature of the limited surface soils in the North Area, fugitive dust generation is not considered a significant transport pathway for PCOC migration. Once in ground water, VOCs may migrate with the ground water and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

It was assumed, as part of the BHHRA, that these media were potentially contacted by the various hypothetical receptors possibly at the Site and, as such, these exposure pathways were potentially complete.

14.1.6 Quantification of Exposure

The goal of the exposure assessment was to provide a reasonable, high-end (*i.e.*, conservative) estimate of exposure that focuses on potential exposures in the actual population. This concept is termed the reasonable maximum exposure (RME) approach. This should not be confused with: (1) a worst-case scenario which refers to a combination of events and conditions such that, taken together, produces the highest conceivable exposure; or (2) a bounding estimate that purposefully overestimates exposure. Thus, in accordance with the EPA's guidance, site-specific exposure assumptions and parameters were used when available and, when not available, assumptions were deliberately chosen to represent a high-end RME estimate. A central tendency or average scenario was also evaluated to provide a range of exposures.

Chemical exposure is quantified by the calculation of an intake, or dose, that is normalized to body weight and exposure time of the receptor. A dose is calculated by combining assumptions regarding contact rate (*e.g.*, intake amount and time, and frequency and duration of exposure) to a contaminated medium with representative chemical exposure point concentrations for the medium of concern at the point of contact. Receptors are chosen based on their exposure patterns that may put them at risk or at a higher risk than other individuals. Intake assumptions, in general, were based on central tendency or RME assumptions determined by the EPA, or were based on information obtained from site-specific studies. RME scenarios use a combination of assumptions, such as average values for physical characteristics of the receptors (*e.g.*, body weight and corresponding body surface area), UCL values (*e.g.*, values at the 90 or 95 percentile of the distribution) for contact rate, and UCL on the mean for the exposure point concentrations. The combination of these factors is assumed to provide an upper-bound estimate of exposure and risk to that particular receptor.

The intake or dose of a particular compound by a receptor is quantified with the following generic equation (EPA 1989):

$$I = \frac{C \times CR \times EFD}{BW} \times \frac{1}{AT} \qquad \text{(Equation 1)}$$

where:

I	=	the compound intake or dose (mg/Kg BW-day);
C	=	the compound concentration (mg/Kg or mg/L);
CR	=	contact rate or the amount of contaminated medium contacted per event (L/day or mg/day);
EFD	=	the frequency (days/year) and duration (number of years) of exposure days;
BW	=	the average body weight of the receptor (Kg); and
AT	=	averaging time of the exposure (days); for noncarcinogens, AT equals (ED) x (365 day/year); for carcinogens, AT equals (70 years over a lifetime) x (365 day/year).

This equation calculates an intake that is normalized over the body weight of the individual and the time of the exposure. Because the intake or dose is combined with quantitative indices of toxicity (*i.e.*, chemical-specific dose-response information such as reference doses [RfDs] for non-carcinogenic compounds or cancer slope factors [CSFs] for carcinogenic compounds) to give a measure of potential risk, the intake or dose must be calculated in a manner that is compatible with the quantitative dose-response information for chemical constituents evaluated in the analysis. Two different types of health effects are considered in this analysis: 1) carcinogenic effects and 2) non-carcinogenic effects (*i.e.*, either chronic or subchronic, depending on the receptor's exposure).

For carcinogenic effects, the relevant intake is the total cumulative intake averaged over a lifetime because the quantitative dose-response function for carcinogens is based on the assumption that cancer results from chronic, lifetime exposures to carcinogenic agents. This intake or dose is then averaged over a lifetime to provide an estimate of intake or dose to carcinogens as "mg/Kg-day," which is expressed as a lifetime average daily dose (LADD). Thus, for potentially carcinogenic compounds, the averaging time (AT) is equal to 70 years (EPA 1989).

Non-carcinogenic effects are evaluated for chronic, subchronic, or acute exposures by receptors to systemic or reproductive toxicants. For non-carcinogenic effects, the relevant intake or dose is based on the daily intake averaged over the exposure period of concern. As defined in EPA guidance (EPA 1989), an exposure period for toxicity can be either acute (*i.e.*, exposure occurring from one event or over one day), subchronic (*i.e.* cumulative exposures occurring from two weeks up to seven years), or chronic (*i.e.* cumulative exposure over seven years to a lifetime in duration). The quantitative dose-response function for non-carcinogenic effects (*i.e.* chronic and subchronic) is based on the assumption that effects occur once a threshold dose is attained from repeated exposure. Therefore, the intake or dose for non-carcinogenic risk assessment is based on an average daily dose (ADD) that is averaged over the duration of exposure. The averaging time for assessing non-carcinogenic effects is equal to the exposure duration for the receptor. In the BHHRA, exposure was assumed to be chronic for all receptors even though some exposures described in this report were intermittent or less than chronic duration.

14.1.6.1 Estimating the Exposure Point Concentration

The general procedure that is recommended by the EPA to estimate a 95% UCL was used as the Exposure Point Concentration (EPC) to represent the upper end of exposure. The EPA's ProUCL Version 4 program (EPA 2007) was used to analyze dataset distribution and calculate average and 95% UCL concentrations. ProUCL calculates various estimates of the 95% UCL of the mean, and then makes a recommendation on which one should be selected as the best UCL estimate. If the 95% UCL was greater than the maximum detected concentration, the maximum measured concentration was used as the EPC.

ProUCL was used to provide output when there were sufficient samples to run statistics (soil and sediment). It should be noted that when evaluating exposure from fugitive dust generation, the EPC was based on surface soil data because it is unlikely that deeper soils (*i.e.*, soils below a depth of 0.5 ft) are transported as wind-borne dust. One-half of the sample detection limit was used for sample measurements below the sample detection limit. There were not enough pond sediment or surface water samples for statistical calculations, so average and maximum measured concentrations were used in the evaluation for these media.

Both averages and 95% UCLs were used in the BHHRA to provide a range of exposure point concentrations and are summarized in Tables 23 through 37. The dose estimates using the 95% UCL EPC were considered to represent RME. The average was used to represent the average or central tendency exposure.

14.1.6.2 Quantifying Intake

To quantify potential exposures associated with the pathways of potential concern, Equation 1 is modified according to the specific exposure routes and intake assumptions.

14.1.6.2.1 Incidental Ingestion of Soil

The intake or dose for the incidental ingestion pathway from soil is calculated based on the following equation (EPA 1989):

$$AD_{ing} = \frac{Con_{soi} \times IR \times FI \times AAF \times EF \times ED \times CF}{BW \times AT} \qquad \text{(Equation 2)}$$

where:

ADD_{ing} = average daily intake of compound via ingestion of soil (mg/Kg BW-day);
$Conc_{soil}$ = exposure concentration in soil (mg/Kg);
IR = ingestion rate (mg soil/day);
FI = fraction ingested (unitless);
AAF = absorption adjustment factor (fraction absorbed);
EF = exposure frequency (days/year);
ED = exposure duration (years);
CF = conversion factor (10^{-6} Kg/mg);
BW = body weight (Kg); and
AT = averaging time (days).

The exposure concentration in the soil ($Conc_{soil}$) is the concentration of a PCOC at the point of contact. Exposure point concentrations represent random exposure over the exposure unit. The ingestion rate (IR) is the amount of soil incidentally ingested per day or event. For soil, the incidental intake values vary according to the receptor and the specific activities or exposure patterns that the receptor is engaged in at the Site. The fraction ingested (FI) relates to the fraction of soil that is contacted daily from the contaminated area. This is highly dependent on the different activities that an individual is engaged in and the number of hours (fraction of time) spent in the contaminated portions of the site (EPA, 1989). The fraction ingested was conservatively assumed to be 100 percent. The absorption adjustment factor (AAF) is used in the ingestion pathway to account for differences in relative absorption for the chemical from the test vehicle (*i.e.*, the material such as soil, food, or solvent in which the chemical was administered in the toxicity study) versus the exposure medium (*i.e.*, soil) and was assumed to be 1.0 unless compound-specific data were available to suggest otherwise. Body weight (BW) varies according to the age range of the receptor. Adult receptors are assumed to weigh 70 kilograms (Kg), which corresponds to the 50^{th} percentile value for all adults, as recommended by EPA (1989). For receptors other than adults, body weight is dependent on the age of the receptor and is calculated as the time-weighted average body weight using values reported from the EPA's guidance titled "Exposure Factors Handbook" (EPA 1997). The exposure frequency (EF) and duration (ED) of the event is based on the particular exposure pattern and activity related to the receptor (EPA 1997). The averaging time is 70 years for carcinogenic effects, and for non-carcinogenic effects depends on the frequency and duration of exposure for the particular receptor (EPA 1989).

14.1.6.2.2 Dermal Contact with Soil

When calculating intake via dermal contact with soil or sediment, Equation 1 is modified slightly to account for skin surface area, soil-to-skin adherence factors, and chemical-specific absorption factors. An intake or dose is quantified from dermal contact with the following Equation 3 (EPA, 1989):

$$ADD_{der} = \frac{Conc_{soil} \times SA \times AF \times AAF \times EF \times ED \times CF}{BW \times AT} \qquad \text{(Equation 3)}$$

where:

ADD_{der} = average daily dose from dermal contact with chemical in soil (mg/Kg-day);
$Conc_{soil}$ = exposure concentration in soil (mg/Kg);
SA = skin surface area available for direct dermal contact (cm^2/event);
AF = soil/sediment to skin adherence factor (mg/cm^2);
AAF = absorption adjustment factor (unitless)
EF = exposure frequency (days or events/year);
ED = exposure duration (years)
CF = conversion factor (10^{-6} Kg/mg);
BW = body weight (Kg); and
AT = averaging time (days).

The exposed skin surface area (SA) is the area or portion of the body exposed for dermal contact. As with many exposure variables, surface area depends on the age and exposure pattern that the receptor is engaged in that relate to repeated or average exposure. Surface area can be predicted based on factors such as activity and types of clothing. Typical exposures via dermal contact for most receptors are generally limited to certain parts of the body (*e.g.*, hands, forearms, head, and neck) since clothing tends to significantly reduce the potential for direct contact with soil (Kissel, 1995). The soil adherence factor (AF) is the density of soil adhering to the exposed fraction of the body. The adherence factor is highly dependent on the specific activity of the receptor as well as physical properties of the soil (*e.g.*, moisture content, textural class, and organic carbon content) (Kissel et al., 1996). The AAF accounts for the relative absorbance of a chemical between dermal exposure from the environmental medium and oral exposure in the critical toxicity study, which was used to derive the dose-response information for that chemical. Therefore, the AAF is highly chemical-specific and, unless otherwise noted, was assumed to be 1.0. Factors such as body weight, exposure frequency, exposure duration, and averaging time are similar to that discussed above for incidental ingestion.

14.1.6.2.3 Inhalation of Volatiles and Fugitive Dusts

An intake or dose from inhalation of vapors or particles emitted from the Site is calculated by modifying Equation 1 to account for the volatilization and/or particulate emission factor and the difference in methodology when evaluating air impacts (*i.e.*, dose was not calculated, but rather an effective air concentration that the receptor may be exposed to was calculated). An effective air concentration was generally calculated using the following Equation 4:

$$EAC = \frac{Conc_{soil} \times VF \times EF \times ED}{AT} \qquad \text{(Equation 4)}$$

where:

EAC = effective air concentration (mg/m^3);
$Conc_{soil}$ = exposure point concentration in soil (mg/Kg);
VF = volatilization factor (mg/m^3-air/Kg-soil) and/or particulate emission factor:
EF = exposure frequency; describes how often exposure occurs (days/year);
ED = exposure duration; describes how long exposure occurs (years); and
AT = averaging time; period over which exposure is averaged (days).

A risk assessment from inhalation of volatiles and dusts is different from the quantification of potential risks from dermal contact or incidental ingestion. Risks from inhalation exposure are based on a comparison of a measured or calculated air concentration (effective air concentration) to a risk-based acceptable air concentration, either a reference concentration (RfC) or an inhalation unit risk (IUR) value. Where monitoring data do not exist, an EPC in air can be calculated based on a volatilization model and/or particulate emissions factor and the EPC in soil. Surface soil data were used when estimating the air concentration for particulate dust generation.

14.1.6.2.4 Exposure Assumptions and Intake Calculations

The exposure assumptions are provided in Tables 39 (Exposure Assumptions for the Industrial Worker Scenario), 40 (Exposure Assumptions for the Construction Worker Scenario), 41 (Exposure Assumptions for the Youth Trespasser Scenario), and 42 (Exposure Assumptions for the Contact Recreation Scenario) for the industrial worker, construction worker, youth trespasser, and contact recreation receptors, respectively. Instead of employing a highly uncertain particulate emission factor and fugitive dust dispersion model to evaluate off-site exposure, potential risks from South Area soil to the nearby off-site residential receptor were conservatively evaluated using the residential PCL for a 30-acre source area for the soil-to-air pathway (inhalation of volatiles and particulates).

14.1.6.2.5 Vapor Intrusion Pathway for Future On-Site Worker Scenarios

Except for the AST Tank Farm, a dry dock, and a former transformer shed, there are currently no structures present on the South or North Areas at the Site. However, future development of the area may result in construction of buildings at the Site. In the event that permanent and enclosed structures are built on-Site in the future, the Johnson and Ettinger Vapor Intrusion Model (J&E VIM) (EPA 2002) was used to assess the potential migration of volatile chemicals from ground water into the breathing space of an overlying building. Exposure estimates are calculated in the model using default exposure parameters for an industrial worker similar to those provided in Tables 39 (Exposure Assumptions for the Industrial Worker Scenario) and 40 (Exposure Assumptions for the Construction Worker Scenario) along with Site-specific soil and hydrogeologic properties. While a construction worker could also be exposed to VOCs migrating from ground water to outdoor air, that exposure and risk scenario was not calculated separately since it is likely to be less than the industrial worker's exposure under the indoor air scenario as there would be greater dispersion and mixing in the ambient outdoor air that a construction worker would encounter (no dispersion and mixing is assumed with the J&E VIM), and because the construction worker's exposure frequency and duration is less than for the industrial worker.

The model was only run for those compounds that are considered volatile since non-volatile compounds would not migrate from the ground water to the overlying soil pore space and to ambient air via this pathway. As noted previously, a restrictive covenant is currently in place for Lots 55, 56, and 57 and requires any building design to preclude vapor intrusion. Thus, this evaluation represents a conservative assessment of the vapor intrusion pathway for these lots.

The site-specific variables used in the J&E VIM model were determined from information gathered during previous Site investigations and presented in the NEDR (PBW 2009). Depth below grade to the bottom of a hypothetical enclosed floor space was assumed to be 15 cm, or the thickness of a typical slab since basement construction was not considered due to the geographic location of the Site. Depth below grade to the water table was conservatively estimated to be 5.0 ft based on water gauging data from both North and South Area monitoring wells. Clay was selected as the soil type directly above the water table, which is the dominant soil type in shallow soils at both the North and South Areas as indicated on the boring logs provided in NEDR (PBW 2009). The average soil/ground water temperature used in the model was 25° C based on the geographical location of the Site and regional climatic conditions.

Both average and RME EPCs were used in the calculations to provide a range of exposure and potential risks. These values are listed in Tables 43 (Johnson and Ettinger Vapor Intrusion Model Output for South Area Ground Water) and 44 (Johnson and Ettinger Vapor Intrusion Model Output for North Area Ground Water).

14.1.7 Toxicity Assessment

The toxicity assessment provides a description of the relationship between a dose of a chemical and the anticipated incidence of an adverse health effect (EPA 1989). The purpose of the toxicity assessment is to provide a quantitative estimate of the inherent toxicity of PCOCs to incorporate into the risk characterization. Toxicity values are derived from the quantitative dose response association and are correlated with the quantitative exposure assessment in the risk characterization.

For risk assessment purposes, toxic constituent effects are separated into two categories of toxicity: carcinogenic effects and non-carcinogenic effects. This division relates to the EPA's policy that the mechanisms of action for these endpoints differ. Generally, the EPA has required that potentially carcinogenic chemicals be treated as if minimum threshold doses do not exist, whereas non-carcinogenic effects are recognized to have a threshold below which toxicity is unlikely.

14.1.7.1 Exposure Route-Specific Toxicity Criteria

In deriving toxicity criteria, the EPA's methodologies consider the route of administration (or exposure) of the test chemical in toxicity or epidemiological studies. Typically oral RfDs and oral CSFs are derived from toxicity studies with oral administration or exposure route, and RfCs or inhalation unit risks are derived from inhalation toxicity studies. While one could attempt to extrapolate an inhalation toxicity criterion to the oral pathway or visa versa, this practice is not recommended because there can be a great deal of uncertainty introduced (EPA 1989). Therefore, in the BHHRA, oral RfDs were not extrapolated to provide toxicity values for inhalation pathways. Quantitative risk evaluation of the inhalation exposure pathways was conducted only for those chemicals that have reference toxicity values specifically from inhalation administration.

The EPA has not derived specific toxicity criteria for the dermal exposure pathway. This presents a complication because oral and inhalation toxicity criteria are based on administered dose and not absorbed dose while dermal exposure pathways consider the absorbed dose (*i.e.*, how much of the chemical in soil or water crosses the skin barrier and is absorbed by the body). The oral RfD or oral CSF can be applied in evaluation of the dermal exposure pathway following adjustment of the oral toxicity criteria for gastrointestinal absorbance. The EPA recommends adjusting oral toxicity criteria by gastrointestinal absorbance factors if gastrointestinal absorbance of the chemical in the vehicle of administration in the critical study is less than 50 percent. Generally, organic chemicals are assumed to be relatively bioavailable in oral and gavage toxicity studies and, thus, the administered dose is likely to be similar to absorbed dose. Therefore, no adjustment of oral toxicity criteria is recommended for organic PCOCs. The EPA recommends adjusting oral toxicity criteria for a number of inorganic constituents based on the possibility of low gastrointestinal absorbance. It should be noted that none of the PCOCs quantitatively evaluated in the BHHRA are recommended for the adjustment described above.

14.1.7.2 Carcinogenic Effects

Potential carcinogenic effects resulting from human exposure to constituents are estimated quantitatively using CSFs, which represent the theoretical increased risk per milligram of constituent intake/kilogram body weight/day $(mg/Kg\text{-}day)^{-1}$ or unit risks, which are the theoretical increased risks per exposure concentration. CSFs or unit risks are typically derived for “known or probable” human carcinogens. CSFs or unit risks are used to estimate a theoretical upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular lifetime daily dose of a potential carcinogen. Constituents that are believed to be carcinogenic may also have non-cancer effects. Potential health risks for these constituents are evaluated for both cancer and other types of effects as described below.

14.1.7.3 Non-Carcinogenic Effects

Unlike carcinogenic effects, it is widely accepted that non-carcinogenic biological effects of chemical substances occur only after a threshold dose is achieved. This threshold concept of non-carcinogenic effects assumes that a range of exposures up to some defined threshold can be tolerated without appreciable risk of harm. Adverse effects may be minimized at concentrations below the threshold by pharmacokinetic processes, such as decreased absorption, distribution to non-target organs, metabolism to less toxic chemical forms, and excretion.

RfD values and reference concentrations (RfCs) are developed on the basis of a wide array of non-carcinogenic health effects. The RfD and RfC are estimates of the daily maximum level of exposure to human populations (including sensitive subpopulations) that are likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 1989). RfDs are expressed in units of daily dose (mg/Kg-day) while RfCs are expressed as an air concentration in milligrams per cubic meter (mg/m^3). Both values incorporate uncertainty factors to account for limitation in the quality or quantity of available data.

14.1.7.4 Sources of Toxicity Criteria

There are a variety of toxicity databases that regulatory agencies rely on for the purposes of quantifying the toxicity of chemicals in the environment. The primary source (*i.e.*, “Tier 1”) for toxicity information in the risk assessment should be the EPA’s Integrated Risk Information System (IRIS). According to a recent EPA directive that revises the human health toxicity value hierarchy, if RfDs for non-carcinogenic compounds and CSFs for possible carcinogens are not available in IRIS, the “Tier 2” toxicity resource is the EPA’s database of Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV). The “Tier 3” resources that can be consulted if IRIS and PPRTV databases lack relevant toxicity criteria include the Health Effects Assessment Summary Tables (HEAST) and the Centers for Disease Control’s Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs). All toxicity values were obtained from EPA’s IRIS on-line database, which was accessed during December 2008.

14.1.8 Risk Characterization

The risk characterization section of the ROD summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk at the Site. Baseline risks are those risks and hazards that the Site poses if no action were taken. Table 45 (Summary of Hazard Indices and Cancer Risk Estimates for Soil and Sediment Exposure) consists of risk characterization summaries that show the calculations for both cancer and non-cancer risk. The BHHRA organized the types of risk at the Site according to various exposure scenarios. Each exposure scenario specifies the type of human receptor (*e.g.*, child resident, adult industrial worker), the exposure pathway (*e.g.*, inhalation, ingestion), and the COC. If a contaminant or exposure scenario is found to produce a risk which will require a remedial action (based on either the carcinogenic risk or the HI) that contaminant or exposure scenario is said to “drive the risk” or “drive” the need for action. A remediation goal is set for Site-related contaminants that drive risk. All carcinogenic risks are based on RME.

14.1.8.1 Carcinogens

For carcinogens, risks are generally expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk (ELCR) is calculated from the following equation:

Risk or ELCR = CDI x SF

where:

Risk or ELCR = a unitless probability (*e.g.*, 2.0×10^{-5}) of an individual developing cancer,

CDI = chronic daily intake (averaged over 70 years) expressed as milligrams per kilogram per day (mg/kg-day), and

SF = slope factor, expressed as $(mg/kg\text{-}day)^{-1}$

These risks are probabilities that are expressed in scientific notation (*e.g.*, 1.0×10^{-6}). An ELCR of 1.0×10^{-6} indicates that an individual experiencing the RME estimate has a 1 in 1,000,000 chance of developing cancer as a result of Site-related exposure. This is referred to as an ELCR because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. The chance of an individual developing cancer from all other causes has been estimated to be as high as one in three. The EPA's generally acceptable risk range for Site-related exposures is 1.0×10^{-4} to 1.0×10^{-6}, or a 1 in 10,000 to a 1 in 1,000,000 chance, respectively, of an individual developing cancer.

14.1.8.2 Noncarcinogens

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period (*e.g.*, life-time) with a RfD derived for a similar exposure period. The ratio of exposure to toxicity is called a hazard quotient (HQ). A HQ less than 1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic non-carcinogenic effects from that chemical are unlikely. The Hazard Index (HI) is generated by adding the HQs for all chemical(s) of concern that affect the same target organ (*e.g.*, liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. A HI less than 1 indicates that, based on the sum of all HQ's from different contaminants and exposure routes, toxic non-carcinogenic effects from all contaminants are unlikely. A HI greater than 1 indicates that site-related exposures may present a risk to human health. The HQ is calculated from the following equation:

Non-cancer HQ = CDI/RfD

where:

HQ = hazard quotient (unitless)

CDI = chronic daily intake (mg/kg-day)

RfD = reference dose (mg/kg-day)

CDI and RfD are expressed in the same units and represent the same exposure period (*i.e.*, chronic, subchronic, or short-term). The EPA assumes additive effects in evaluating non-carcinogenic effects from a mixture of chemicals. Additivity should only be assumed for chemicals that induce the same effect by the same mechanism of action. This consideration is often addressed by adding HIs for chemicals that critically affect the same target organ system. This additivity across chemicals affecting the same target organ has been addressed in this assessment. The constituent-specific hazard quotients are summed to yield an overall pathway

HI. Pathway HIs are then summed to yield a total HI for each relevant population.

Risk characterization involves estimating the magnitude of the potential adverse health effects under study. This was accomplished by combining the results of the toxicity assessments and exposure assessments to provide numerical estimates of potential health effects. These values represent comparisons of exposure levels with appropriate toxicity threshold values and estimates of excess cancer risk. Risk characterization also considers the nature of and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding such estimates. Although the risk assessment produces numerical estimates of risk, these numbers do not predict actual health outcomes. The estimates are calculated to overestimate risk, and thus any actual risks are likely to be lower than these estimates, and may even be zero.

Generally, the EPA considers a remedial action to be warranted at a site where the ELCR exceeds 1 x 10^{-4}. The need for action for risks falling within the 1 x 10^{-4} to 1 x 10^{-6} range is judged on a case-by-case basis, unless applicable or relevant and appropriate requirements are exceeded. Risks less than 1 x 10^{-6} generally do not require remedial action. The point of departure for evaluating ELCR (individual carcinogens) is 1 x 10^{-6}. A hazard quotient or hazard index greater than one indicates some potential for adverse non-cancer health effects associated with COCs.

Risk characterization is the integration of the exposure and toxicity information to make quantitative estimates and/or qualitative statements regarding potential risk to human health. This section describes the risk characterization process for carcinogenic and non-carcinogenic PCOCs.

The BHHRA evaluated site-specific exposures based on realistic current and possible future land use. Table 45 (Summary of Hazard Indices and Cancer Risk Estimates for Soil and Sediment Exposure) provides a summary of the HIs for each scenario using average and RME assumptions for the soil pathways. None of the HIs for the soil exposure pathways exceeded EPA's target hazard index of 1. Exposure from the vapor intrusion pathway from PCOCs in ground water for a hypothetical industrial worker employed in a building sited at the North Area resulted in an HI greater than 1, as shown in Table 44 (Johnson and Ettinger Vapor Intrusion Model Output for North Area Ground Water). Potential cancer risks in the North Area were predicted to be 2.0 x 10^{-2}, which is 200 times greater than the EPA's risk level of 1.0 x 10^{-4}. This means that for every 10,000 people that could be exposed 200 extra cancer cases may occur as a result of exposure to Site-related contaminants (*i.e.* VOCs) via the ground water to indoor air pathway. The HI was estimated to be 18.0 indicating that non-cancer health effects are possible via this pathway.

In calculating the risks posed by the Site, the BHHRA assumed that the future land use of the Site would be restricted to commercial/industrial land use; risk calculations for residential land use generally assume greater exposures. The BHHRA also assumed that the Site ground water would not be used and the continuing integrity of the cap on the former surface impoundments. If the integrity of the cap were not maintained, there would be additional potential risks under the contact recreation scenario, as discussed below, as well as potential risks of direct skin contact as a result of exposure to contaminated sludges now covered by the cap by future on-site workers and potential current youth trespassers.

It should be noted also that due to lead's unique toxicological properties, noncancer risk estimates could not be calculated similarly to the other non-carcinogenic PCOCs. However, none of the measured concentrations of lead in Site soil exceeded the EPA's screening level for industrial properties of 800 mg/kg. Thus, it is unlikely that lead at the Site poses an unacceptable risk.

14.1.8.3 Contact Recreation Scenario

Exposure to sediment and surface water by the youth trespasser and contact recreation receptor were evaluated using TCEQ's contact recreation PCLs for these media. None of the PCOCs detected in these media exceeded their respective PCLs. As such, exposure to PCOCs in these media is unlikely to result in an adverse health risk.

Zone A ground water intersects the Intracoastal Waterway in areas adjacent to the Site. In the areas where this intersection occurs, the ground water/surface water discharge relationship shows both short- and long-term variations depending on Zone A potentiometric levels and the tidal stage of the waterway. Regardless of the specific recharge/discharge condition at a given point in time, the net flux between Zone A and the Intracoastal Waterway is likely to be relatively low given: (1) the low hydraulic conductivity of Zone A, (2) the limited thickness of the unit adjacent to the shoreline, and (3) the relatively low magnitude of tidal range fluctuations within the waterway.

Contaminated ground water from the North Area of the Site does not discharge to the surface water and sediments of the Intracoastal Waterway adjacent to the South Area. The lateral extent of Site ground water containing COIs at concentrations above extent evaluation criteria is generally limited to a localized area within the North Area, roughly over the southern half of the former surface impoundments area and a similarly sized area immediately to the south.

The clay cap covers the former surface impoundments and prevents rainwater from infiltrating into the source area. If the cap was not present, or is not maintained in the future, then infiltration into the source area would increase and accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments.

A conservative qualitative assessment determined that the undiluted concentrations of ground water COIs discharging into the waterway could pose a risk to contact recreation receptors. As an example, the maximum reported concentration for Zone A ground water of

292.0 mg/L for 1,2-DCA is more than three (3) orders of magnitude higher than the TRRP PCL of 0.196 mg/L. Another example shows that the maximum reported concentration for Zone A ground water of 234.0 mg/L for 1,1,1-TCA is almost five (5) times higher than the TRRP PCL of 47.2 mg/L. This conservative qualitative assessment shows that contact recreation receptors could be at risk, through ingestion and dermal contact, if the Zone A impacted ground water reached the Intracoastal Waterway’s surface water and sediments.

14.1.8.4 Off-Site Residential Scenario

Off-site residential receptor risks were estimated by comparing PCOC concentrations in on-Site soil samples to their respective TCEQ’s PCLs that were developed to evaluate exposure to air emissions from particulate dust and VOCs emitted from contaminated soil. This approach is conservative since diluting effects of off-site migration and dispersion were not considered. Even so, unacceptable risks are not expected since none of the compounds measured in South Area soils exceeded the screening criteria (see Tables 41 [Exposure Assumptions for the Youth Trespasser Scenario] and 42 [Exposure Assumptions for the Contact Recreation Scenario]).

14.1.8.5 Future On-Site Industrial Worker Vapor Intrusion Pathway Risk Estimates

As part of the BHHRA, the EPA determined the “Incremental Risk from Vapor Intrusion to Indoor Air, Carcinogen (unitless)” and “Hazard Quotient from Vapor Intrusion to Indoor Air, Noncarcinogen (unitless).” The results of this evaluation are presented in Tables 43 (Johnson and Ettinger Vapor Intrusion Model Output for South Area Ground Water) and 44 (Johnson and Ettinger Vapor Intrusion Model Output for North Area Ground Water) for the North Area and South Area, respectively, and suggest that, under the conservative assumptions of the J&E VIM, a potential unacceptable risk is likely at the North Area in the event that a building is constructed over the Zone A ground water plume and vapor intrusion occurs similar to the model’s predictions. As noted previously, this conservative evaluation does not consider the restrictive covenants for Lots 55, 56, and 57 that require building design to exclude vapor intrusion.

14.1.9 Uncertainty Analysis

Uncertainties are inherent in every aspect of a quantitative risk assessment. The inclusion of site-specific factors can decrease uncertainty, although significant uncertainty persists in even the most site-specific risk assessments. Worst-case assumptions and default values, which conform to EPA guidance (EPA 1989), add conservatism to human health risk assessments. This conservatism is intentionally included in order to tilt the assessment toward over-prediction of risk and hence protection of human health. It is important to the risk management decision-making process that the sources of uncertainty are provided. Therefore, sources of uncertainty related to the identification of PCOCs, exposure assessment, and toxicity assessment of the BHHRA were identified and qualitatively.

14.1.9.1 Impact of Uncertainties

Efforts were made in the BHHRA to purposefully err on the side of conservatism in the absence of site-specific information. It is believed that the overall impact of the uncertainty and conservative nature of the evaluation results in an overly protective assessment. Therefore, for scenarios with risks and HIs within or below the Superfund risk range goal and target HI, it can be said with confidence that these environmental media and areas do not present an unacceptable risk.

14.1.10 Conclusions of the Baseline Human Health Risk Assessment

The primary objective of the BHHRA was to evaluate the possible risks associated with PCOCs in environmental media on human receptors at the Site. This information was used to help guide future risk management decisions at the Site. The risk assessment methodology used to conduct this analysis was based on the approach described by the EPA in various supplemental and associated guidance documents as documented throughout the report.

Data were segregated by media and by location (*e.g.*, North Area soil and South Area soil; and Intracoastal Waterway sediment and wetlands sediment) and distribution testing was performed. EPCs were estimated for all PCOCs for both central tendency (average) and RME (95% UCL) exposures using EPA's ProUCL program.

Five different exposure scenarios were quantitatively evaluated for the thirteen different potentially contaminated media identified at the Site. Exposure scenarios were developed to describe current and potential future land use by various human receptors and included a future industrial worker, future construction worker, current youth trespasser, current contact recreation receptor, and current off-site residential receptor. Exposure and risks were calculated for both central tendency and RME scenarios.

The BHHRA concluded that there were no unacceptable cancer risks or noncancer hazard indices for any of the current or future exposure scenarios, except for future exposure to an indoor industrial worker if a building is constructed over impacted ground water in the North Area. In reaching this conclusion the BHHRA assumed the continuing integrity of the Site cap on the former surface impoundments and did not address risks if the cap were not present and not maintained. The BHHRA also assumed use of the Site being restricted to commercial/industrial land use, and that the Site ground water would not be used. If any of these three assumed conditions were to change in the future, then the conclusions of the BHHRA would not be valid.

Potential cancer risks in the North Area, using maximum shallow Zone A ground water concentrations and the J&E VIM model, were predicted to be greater than 1.0×10^{-4}, while the HIs were estimated to be greater than 1. Generally, the EPA considers a remedial action to be warranted at a site where the ELCR exceeds $1.0 \times 10^{\mathbf{-4}}$. The need for a remedial action for risks falling within the 1.0 x 10^{-4} to 1.0 x 10^{-6} range is judged on a case-by-case basis (unless applicable or relevant and appropriate requirements are exceeded). Risks less than 1.0 x 10^{-6} generally do not require a remedial action. The point of departure for evaluating ELCR for individual carcinogens is 1.0 x 10^{-6}. An HQ or HI greater than 1 indicates some potential for adverse non-cancer health effects associated with the COCs for the Site.

Potential cancer risks in the North Area were predicted to be 2.0 x 10^{-2}, which is 200 times greater than the EPA's risk level of 1.0 x 10^{-4}. This means that for every 10,000 people that could be exposed 200 extra cancer cases may occur as a result of exposure to Site-related contaminants (*i.e.* VOCs) via the ground water to indoor air pathway. The HI was estimated to be 18.0 indicating that non-cancer health effects are possible via this pathway. It should be noted that this scenario was evaluated despite the current restrictive covenant on Lots 55, 56, and 57 that require future building design to preclude vapor intrusion, which would effectively make this pathway incomplete. Estimated risks from Zone A ground water at the South Area were below the EPA's goals; therefore, adverse risks associated with the vapor intrusion pathway are unlikely in this area.

14.2 Summary of the Ecological Risk Assessment

All of the ecological risk assessment activities at the Site were performed under the EPA's 8 step process and guidance titled "Ecological Risk Assessment Guidance for Superfund: Process for Defining and Conducting Ecological Risk Assessments" (ERAGS, EPA 1997) and certain aspects of the TCEQ's "Ecological Risk Assessment" guidance. With the submittal of the Final Baseline Ecological Risk Assessment (BERA), all 8 steps were completed. The first phase in the ecological risk process, the Screening-Level Ecological Risk Assessment (SLERA, PBW 2010a), concluded that there were no upper trophic level risks to ecological receptors consuming food or soil, sediment, and surface water media containing site-related contaminants of potential ecological concern (COPECs). However, the Scientific/Management Decision Point (SMDP) provided in the Final SLERA concluded that a potential was indicated for adverse toxicological ecological effects to soil- and sediment-dwelling invertebrates for the following COPECs: PAHs, metals, and pesticides. Thus, a more thorough Baseline Ecological Risk Assessment (BERA, URS 2011) was warranted, and subsequently conducted.

The BERA Work Plan and Sampling and Analysis Plan (SAP) and BERA Problem Formulation were approved by the EPA, and sample collection, laboratory analysis, and data validation were conducted. The BERA Work Plan summarized the field activities, toxicity testing, chemical analyses and data validation. Following the EPA's approval of the Preliminary Site Characterization Report (PSCR), the draft BERA Report was submitted to the EPA.

The BERA Work Plan and SAP described a study to assess site-specific toxicity to invertebrates to COPECs in the North Area soils, wetland sediments, Intracoastal Waterway sediments, and surface water from the wetland area. Toxicity testing of sediment was conducted using the 28-day whole-sediment tests for the polychaete *Neanthes arenaceodentata a*nd the amphipod *Leptocheirus plumulosus* using the wetland sediments and Intracoastal Waterway sediments. A 21-day whole-sediment/soil toxicity test using *Neanthes arenaceodentata* was applied to the North Area soils. The bioassays for the surface water were conducted on brine shrimp (*Artemia salina*) and assessed at a 48-hour duration. All of the BERA sediment and soil sample locations were chosen based on a concentration gradient of the COPECs identified in the SLERA. The objective of the BERA Report is to characterize the Site-specific risks using samples of surface soil, surface sediment, and surface water in accordance with the study design identified in the Final BERA Work Plan and SAP.

The evaluation of toxicity and analytical data showed that the most relevant comparison was between Site and reference sample locations. This approach allows for a comparison of locations that exhibit similar environmental conditions, except for the presence of Site-related COPECs. Ultimately, it was determined that there is no statistically significant difference in the toxicity observed in samples collected at the reference locations and the Site for sediment/soil exposure and that there was no toxicity associated with the surface water locations. Because of the lack of evidence of Site-related toxicity, development of ecologically-based remediation goals was not necessary.

14.2.1 Screening Level Ecological Risk Assessment (Steps 1 and 2)

The purpose and scope of the SLERA was to summarize the analytical data for environmental media sampled during the RI and to complete Steps 1 and 2 of the EPA's Ecological Risk Assessment process based on those data. The SLERA was a conservative assessment and served to evaluate the need and, if required, the level of effort necessary to conduct a BERA. A SLERA is to provide a general indication of the potential for ecological risk (or lack thereof), and was conducted for several purposes including: 1) to estimate the likelihood that a particular ecological risk exists; 2) to identify the need for site-specific data collection efforts; or 3) to focus site-specific ecological risk assessments where warranted (EPA 1997).

The SLERA (PBW 2010a) compared maximum concentrations of the COPECs to protective ecological benchmarks for direct contact toxicity. The SLERA concluded that there might be the potential for adverse impacts to sedentary biota communities in surface soil from several COPECs that exceeded a Hazard Quotient (HQ) of 1 in the South Area and North Area. A Hazard Quotient is obtained by dividing each ecological receptor's exposure to each COPEC concentration by the protective toxicity effects criterion for each COPEC. In addition, the SLERA indicated a potential for localized adverse ecological effects to sedentary biota communities in sediment. Concentrations of the COPECs that exceeded the midpoint of the toxicity effects range-low and effects range-median (ERL and ERM) concentration levels in sediment of the North Area wetlands, Intracoastal Waterway and the Ponds were predicted to have toxic effects. The SLERA also concluded that there was a possible risk from direct toxicity to aquatic species, including fish, due to acrolein and dissolved copper in the surface water of the

North Area wetlands and silver in the surface water of the Ponds and the Background Intracoastal Waterway area.

It should be noted that the SLERA determined that adverse effects resulting from soil ingestion, sediment ingestion, surface water and/or food chain exposures to higher trophic-level receptors were unlikely or insignificant because HQs for higher trophic-level receptors were less than 1.

14.2.2 Baseline Ecological Risk Assessment Problem Formulation (Step 3)

Following completion of the SLERA, the BERA Problem Formulation was conducted to identify the specific ecological issues at the Site and determine the scope and goals of the BERA. The BERA Problem Formulation further refined or identified the COPECs; characterized ecological effects of the COPECs; reviewed fate and transport, complete exposure pathways, and potential ecosystems at risk; determined assessment endpoints (specific ecological values to be protected); and developed a CSM with ecological risk questions to be addressed.

Steps were taken to refine the COPEC list (*i.e.*, modification of conservative exposure assumptions and review of spatial COPEC distributions) and conduct a literature research to further characterize ecological effects of the refined list of COPECs, as well as to review their fate and transport characteristics relative to Site conditions. Subsequent to these steps, the following ecosystems were identified as potentially at risk for the following COPECs:

- Wetland sediments and surface water: The primary COPECs with HQs greater than 1 in wetland sediment were several PAHs. Most of the HQ exceedances for the PAHs were located in three areas: (1) a small area immediately northeast of the capped surface impoundments; (2) a smaller area immediately south of the capped surface impoundments; and (3) at a sample location in the southwest part of the North Area approximately 60 ft north of Marlin Avenue. Other COPECs included the organochlorine pesticides and metabolites (4,4’-DDT, endrin aldehyde, and endrin ketone). The metals that were COPECs included arsenic, copper, lead, nickel, and zinc. Additionally, total acrolein and dissolved copper were surface water COPECs in the wetland area northeast of the capped surface impoundments. The COPECs in the Small Pond included 4,4’-DDT and zinc in the sediments and silver in the surface water.

- Intracoastal Waterway sediment within former Site barge slips: The predominant COPECs in these areas, as reflected by HQ exceedances, were PAHs. The total PAH concentration was highest in the northernmost sample in the western barge slip. In the eastern barge slip, the COPECs were three PAHs, hexachlorobenzene, and the sum of high molecular-weight PAHs (HPAHs). The only organochlorine pesticide COPEC was 4,4'-DDT.

- North Area soils south of the capped surface impoundments: The metals COPECs in this area, where some buried debris was encountered in the shallow subsurface, were barium, chromium, copper, and zinc. Organic COPECs included 4,4'-DDT and Aroclor-1254.

The risk questions developed through the BERA Problem Formulation were:

1. Intracoastal Waterway and Wetlands sediments: Does exposure to COPECs in sediment adversely affect the abundance, diversity, productivity, and function of sediment invertebrates as an aquatic community?

2. Wetlands and Pond surface water: Does exposure to COPECs in surface water adversely affect the abundance, diversity, productivity, and function of water-column invertebrates and fish?

3. North Area soils: Does exposure to COPECs in soil adversely affect the abundance, diversity, productivity, and function of soil invertebrates as a terrestrial community?

Justification for removal of the South Area from the ecological risk process was provided in the approved Final BERA Problem Formulation Report (URS 2011) for the following habitat-related considerations:

1. It is zoned by the City of Freeport as "W-3, Waterfront Heavy", which provides for commercial and industrial land use, primarily port, harbor, or marine-related activities;

2. A restrictive covenant placed on the deed ensures that future land use for this parcel of land is commercial/industrial;

3. The area does not serve as valuable habitat, foraging area, or refuge for ecological communities, including threatened/endangered or otherwise protected species;

4. The area does not contain consistent and contiguous habitat but, rather, the area is broken up by the presence of concrete slabs, pads, driveways, and areas of compacted shell;

5. The area exhibits minimal ecological functions because of the disturbed nature of the land and historical industrial use of the property and adjacent properties; and

6. There are minimal, if any, attractive features at the South Area that would support a resident wildlife community.

The Site has been used for industrial purposes since it was developed in the early 1960s. It is also bounded by former and/or current industrial properties to the east and west. The Site has not been used since approximately 1999 and opportunistic grasses and small shrubs have grown on some portions of the South Area that do not have concrete, oyster shell, or gravel cover. The EPA believes that the South Area will be used in the future for commercial/industrial purposes since the barge slips are valuable to many types of businesses in the area, and it is unlikely that the Site will return to “natural” conditions. The evidence indicates that the South Area soils do not represent a valuable ecological resource that warranted further evaluation in order to protect invertebrates such as earthworms and, therefore, there was no further assessment of the South Area soils (URS, 2011).

14.2.3 BERA Work Plan – Study Design and Data Quality Objectives (Step 4)

The BERA Work Plan was prepared to describe the investigation components necessary to complete the BERA. The Work Plan included a SAP that established the specific sampling locations, equipment, and procedures to be used during the BERA. The overall objective to be addressed by the BERA is to evaluate the specific contaminants, pathways, and receptors identified in the SLERA as warranting additional investigation. Data Quality Objectives (DQOs) were established for the BERA through the Problem Formulation steps to identify the assessment endpoints and risk questions (Table 46 – Assessment Endpoints and Measures). The DQOs were based on the proposed end uses of data generated from sampling and analytical activities. The DQOs are qualitative and quantitative statements that outline the decision-making process and specify the required data.

14.2.3.1 BERA Exposure Analysis

To address the BERA objectives and risk questions listed in the Problem Formulation (URS, 2010b), an investigation program was developed that used multiple lines of evidence including sediment toxicity testing, surface water toxicity testing, measures of COPEC bioavailability, and COPEC concentration data.

The investigation program included bioassays of invertebrates coupled with chemical analyses of soil, sediment, pore-water, and surface water. The bioassays, chemical analyses, and determination of COPEC bioavailability represent three lines of evidence that were used to support the conclusions of the BERA. The analyses were selected to incorporate the media, pathways, and COPECs relevant to the assessment endpoints (Table 46 – Assessment Endpoints and Measures). Sampling, analysis, and data evaluation protocols were selected to ensure that the data collected are scientifically defensible and applicable to the BERA objectives. Sample station locations were selected based on COPEC concentrations along a gradient. Sampling locations are provided on Figures 62 (North Area Soil Sample Locations), 63 (Wetland Sediment Sample Locations), 64 (Intracoastal Waterway Sediment Sample Locations), 65 (Intracoastal Waterway Reference Sediment Sample Locations), and 66 (Wetland Surface Water Sample Locations).

14.2.4 Field Verification of Sampling Design (Step 5)

The purpose of the Field Verification of the Sampling Design (Step 5) is to evaluate the appropriateness and implementability of the testable hypotheses, exposure pathway model, and measurement endpoints created in Steps 3 and 4 (EPA 1997). There were two significant adjustments to the toxicity testing protocol: 1) the test species for the North Area soil was changed from the earthworm (*Eisenia fetida*) to the polycheate *Neanthes arenaceodentata* and the soils were treated as sediments in the toxicity testing, and 2) the surface water test species was changed from Mysid shrimp (*Mysidopsis bahia*) to brine shrimp (*Artemia*). Both of these adjustments were due to the elevated salinity commonly found in the salt panne environment.

14.2.5 Site Investigation and Data Analysis Phase (Step 6)

Field activities and laboratory testing were conducted in August and September 2010 to support the BERA. Sample collection methods, the pore-water extraction method, field measurements procedures, laboratory analytical methods, toxicity testing methods, and data validation procedures were specified in the Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP) and/or Final BERA Work Plan and SAP. BERA field activities were also conducted in accordance with the Site-specific Health and Safety Plan.

14.2.6 Environmental Media Sampling

The initial environmental media sampling program consisted of collecting samples for the analyses of those COPECs listed in the Final BERA Work Plan and SAP. Total organic carbon (TOC) data were obtained for the sediment samples from the wetlands area and the Intracoastal Waterway. Simultaneously-extracted metals/acid volatile sulfides (SEM/AVS) and grain size analysis were obtained for the wetland sediments. Data gathered in the field such as water depth, pH, conductivity, temperature, salinity and dissolved oxygen for water and pH, oxygen reduction potential and temperature are shown on Tables 47 (Field Sampling Parameters – Water) and 48 (Field Sampling Parameters – Sediment).

The pore water sample EWSED04PW collected in August 2010 could not be analyzed for PAHs due to a laboratory error. Field activities were re-initiated in September 2010 to collect the pore water sample from the same location. While the sampling team was present on the Site, they evaluated whether sufficient pore water was present at EWSED03, EWSED05, and EWSED09 (as well as sufficient surface water from EWSW02 and EWSW03) that had previously been dry. All of these pore water and surface water samples, except for EWSED05PW and EWSW02, were subsequently collected in September 2010.

Consistent with the BERA Work Plan and SAP, there were no analytical samples formally archived for this project.

14.2.7 Toxicity Testing Protocols

Toxicity testing of sediment was conducted using the 28-day whole-sediment tests for the polychaete *Neanthes arenaceodentata* and *Leptocheirus plumulosus* using the wetland sediments and Intracoastal Waterway sediments. Responses of test organisms exposed to laboratory control samples for all of the sediment toxicity tests indicated that the test organisms were of acceptable health. Additionally, the reference and Site toxicant tests were within acceptable quality control parameters. The purpose of the laboratory control tests is to determine the validity of the test. The sediment used for the laboratory controls is taken from the York River in Virginia, processed to remove vegetative matter, and then frozen to remove live indigenous organisms that could prey upon the test species. The effect of freezing the sediments on the health of the test organisms is unknown, although it likely imparts little uncertainty in the analysis since it is commonly performed and follows standard procedures.

Conducting the 28-day earthworm (*Eisenia fetida*) bioassays for North Area soils was problematic given significantly elevated salinity levels in the six (6) Site and three (3) reference soil sample locations. When the earthworms were introduced to the North Area soil samples in the laboratory, there was an immediate avoidance reaction followed by acute mortality in all of the Site and reference location samples. The elevated salinity levels are believed to be due to frequent inundation with estuarine water related to storm events. Also, much of the soil/sediment in the North Area uplands was originally dredge spoils from the Intracoastal Waterway used as fill material. An alternative method for the earthworm bioassays was developed. The nine (9) soil samples from this transitional area were treated as sediment by adding synthetic seawater, and the polychaete *Neanthes arenaceodentata* was exposed over a 21-day test duration with growth and survival endpoints. According to the National Oceanic and Atmospheric Administration (NOAA), survival and growth endpoints “are about equal sensitivity” for *Neanthes arenaceodentata* (MacDonald et al., 2003). Polychaetes are more phylogenetically and taxonomically similar to earthworms than amphipods, such as *Leptocheirus plumulosus*, and are members of the “sediment-ingesting invertebrate” feeding guild that the earthworm was chosen to represent. The 21-day test duration is conservative given the ephemeral nature of the inundation events at the Site.

Similar to the North Area soils, elevated salinity levels measured in August 2010 were also a concern for surface water samples EWSW01 and EWSW04. As-received salinities of 40‰ and 39‰, respectively, were measured by PBS&J Environmental Toxicology Laboratory, and would likely result in significant stress to the mysid shrimp (*Mysidopsis bahia*) proposed in the Final BERA Work Plan and SAP. As previously discussed, these elevated salinity levels are indicative of a salt panne. Therefore, the bioassays for the surface water were conducted on brine shrimp (*Artemia salina*) that are better suited for high salinities. There are no standard laboratory methods for testing chronic exposures to brine shrimp. Therefore, PBS&J Environmental Toxicology Laboratory developed a standard operating procedure (SOP) for conducting acute tests with a survival endpoint by referencing standard procedures for determining toxicity from produced (oilfield) waters. This shortened test protocol, from 7 days to 48 hours, is more representative of the ephemeral nature of surface water in the areas being evaluated and was demonstrated with the toxicity testing to be more reliable. Use of the alternative species and test protocol was approved by the EPA at a test duration of 48 hours.

The surface water toxicity tests with *Artemia* were conducted three times between September and October 2010. The initial test was potentially affected by a laboratory technician using an incorrect food for the test organisms; however the lab control showed 100% survival at 48 hours. The second test exhibited excessive control mortality (failure) (*i.e.*, less than 90% survival of the control) after 48 hours, and the third test was completed with excessive control mortality (failure) after 96 hours but acceptable lab control survival at 48 hours (90%). The applicability of the 96 hour test duration is questionable. It was decided that the original test duration of 96 hours was not acceptable for this test species and site conditions, and that the test duration of 48 hours would be the accepted test duration.

For the evaluation of the toxicity of Site sediment and soil samples, the most relevant comparisons are the results for reference location samples. This enables the comparison of results between Site samples and reference samples that exhibit similar environmental conditions, but are not influenced by releases from the Site. It should be noted that reference samples may contain background concentrations of one or more naturally occurring metals as well as anthropogenic constituents that are not related to Site activities (EPA, 2002).

14.2.8 Results of Chemical Analyses and Toxicity Testing

Chemistry data generated from the BERA sampling and analyses were compared to the previously-collected data to evaluate the COPEC concentration gradients across the Site. The 2010 BERA data were also compared to the applicable screening benchmarks as listed in the BERA Work Plan and SAP (Table 49 – Summary of Results for Wetland Sediment). TCEQ's guidelines are the primary source for the screening benchmarks. Site investigation activities are described by environmental medium and/or area in the following sections. The following text provides a discussion of the COPEC gradients, screening level and/or reference location concentration (*i.e.*, not Site related) exceedances, and corresponding toxicity testing results with supporting tables and figures. The statistical analysis of the toxicity test results is discussed by study area. Table 50 (Summary of Toxicity Testing for Soil and Sediment) is a summary of the toxicity testing results for each of the study areas without statistical comparison of the Site samples with reference samples; however, note that the mean growth and mean survival toxicity results are based on multiple replicates of the test chambers per sample. Thus, results presented in the tables throughout the BERA, should be considered as a mean calculation of the replicates and not a single test result. The determination of the statistical comparison is based on the methods outlined in the BERA Work Plan and SAP which describes that significant differences for the toxicity tests set at $P < 0.05$. Discussion of the statistical and biological significance of the data is presented in the following sections.

14.2.8.1 North Area Soil

There were six (6) Site and three (3) reference samples collected. Samples were collected from the 0 to 0.5 foot depth. The COPECs for the North Area soil are 4,4'-DDT; Arochlor-1254; barium; chromium; copper; and zinc.

14.2.8.1.1 Ecological Setting

The North Area soils represent areas that are topographically higher than the wetland sediments, and are subject to flooding from extreme rainfall or storm surges. Therefore, the area does not represent an upland terrestrial area, but more of a transitional area between wetland sediments and soils. The dominant crustacean in such a transitional area is typically the fiddler crab (*Uca spp.*). Fiddler crabs were noted by the field crew to be present during sample collection. They are detritivores that feed near their burrows during low tide by separating organic detritus from sediment using specialized legs. The burrowing crabs, the marsh crab (*Sesarma cinereum*), and the land crab (*Cardisoma guanhumi*) are also typical of high marsh environments. The primary food source for the marsh crab is *Spartina* detritus, but it will eat small fiddler crabs when they are available. The land crab is an omnivorous scavenger. Both species are eaten by mammalian predators, such as raccoons and coyotes. Other crustaceans often present in the transitional area are hermit crabs (*Clibanarius vittatus* and *Pagurus longicarpus*). Hermit crabs move frequently between the intertidal marsh and the high marsh and are omnivorous scavengers that seek out animal tissues and other organic detritus.

14.2.8.1.2 Analytical Chemistry Results

In general, the 2010 BERA analytical results for North Area soils are lower than the analytical results from the RI data collected in 2009. Table 51 (Summary of Results for North Area Soil), for Site and reference sample locations, shows the BERA data with exceedances of the benchmarks for barium, chromium, copper and zinc. The COPECs 4,4'-DDT and Aroclor-1254 are the only two organic COPECs with exceedances of marine sediment benchmarks (Table 51), which are the ERL conservative screening criteria. A concentration gradient for the two (2) organic COPECs was not apparent from the 2010 data, but is apparent for the inorganic COPECs (see Table 51).

14.2.8.1.3 Toxicity Results

The results from the North Area soils toxicity tests showed no statistically significant differences in toxicity results using the test species *Neanthes arenaceodentata* in Site samples when compared to the reference locations. As shown on Tables 50 (Summary of Toxicity Testing for Soil and Sediment) and 51 (Summary of Results for North Area Soil), mean survival rates ranged from 76% to 96% in the North Area soil samples. The toxicity results did not consistently correlate with the results of the analytical chemistry.

14.2.8.2 Wetland Sediment

There were seven (7) Site and two (2) reference area samples collected as shown on Figure 63 (Wetland Sediment Sample Locations). Sediment samples were collected from the 0 to 0.5 foot depth. Sediment pore water was extracted and analyzed for COPECs for all but one sediment sample (EWSED05) which was too dry to extract pore water. There was not a formal assessment of benthic invertebrates in the samples during the field event; however, polychaete worms and fiddler crabs were observed in all of the wetland sediment sample locations, including the reference locations. The COPECs for the wetland bulk sediment and pore-water include 2-methylnaphthalene; 4,4’-DDT; acenaphthene; acenaphthylene; anthracene; arsenic; benzo(a)anthracene; benzo(a)pyrene; benzo(g,h,i)perylene; chrysene; copper; dibenz(a,h)anthracene; endrin aldehyde; endrin ketone; fluoranthene; fluorene; gamma-chlordane; indeno(1,2,3-cd)pyrene; lead; nickel; phenanthrene; pyrene; and zinc.

14.2.8.2.1 Ecological Setting

The wetland sediment area can be considered a salt panne. In general, the intertidal zone receives nutrients flushed from the supra-tidal zone and nutrients that are filtered out of near-shore waters; however, the area is hyper-saline, and conditions are considered harsh. Similar to the North Area soil, the dominant crustacean in this area is the fiddler crab. Juvenile blue crabs, which may also be present, take refuge in the marsh areas, but migrate to the subtidal zone as they get larger. Mud crabs (*Neopanope texana* and *Panopeus herbstii*) typically live in shallow mud or under shoreline debris and feed on oyster spat, barnacles, snails and smaller crabs. Other crustaceans that may live in the area are hermit crabs (*Clibanarius vittatus* and *Pagurus longicarpus*) and mud shrimp (*Callianassa jamaicense*). All are omnivorous scavengers that feed on organic detritus trapped in marsh sediment.

14.2.8.2.2 Analytical Chemistry Results

In general, the 2010 BERA analytical results for wetland sediments were lower than the analytical results from the RI data collected in 2008. Table 49 (Summary of Results for Wetland Sediment) shows exceedances of the sediment benchmarks for several individual PAHs and metals (lead, nickel and zinc) in the BERA samples. The only exceedances of surface water benchmarks from Site wetland sediment pore-water were for endrin aldehyde, endrin ketone, copper, and zinc. The only exceedances of either sediment or surface water benchmarks in the reference samples were 4,4'-DDT in sediment, and 4,4'-DDT, endrin aldehyde, and nickel in sediment pore-water. As shown on Table 49, concentration gradients were identified for the majority of the COPECs.

Detailed information on sediment grain size and SEM/AVS analytical results are presented on Table 52 (Summary of Grain Size Data for Wetland Sediment) and Table 53 (Summary of AVS, SEM and Organic Carbon-Normalized Excess SEM Data for Wetland Sediment), respectively. The SEM/AVS ratios presented in Table 53 are all above 1.0, except for EWSED08 with an SEM/AVS ratio of 0.157, which indicates that the potential exists for metal toxicity since sufficient AVS to completely form insoluble metal sulfides is not present. However, sediment organic carbon can also bind the free metals and reduce their availability to aquatic organisms. The ratio of "excess" SEM to the fraction organic carbon content of sediment was below 130 micromoles per gram organic carbon ($\mu mol/g_{oc}$), the concentration predicted to be non-toxic by the EPA, for six (6) of seven (7) Site samples. Also, the remaining Site sample (EWSED06) had an organic carbon-normalized excess SEM ratio of 168, which is at the low end of the range where the prediction of toxicity is uncertain (130 to 3,000 $\mu mol/g_{oc}$). The sediment grain size data presented in Table 52 are fairly consistent between locations, except for the relatively high fraction of gravel and low fraction of clay found at EWSED02 and EWSED03, as compared to the opposite situation of low fraction of gravel and high fraction of clay at EWSED01, EWSED04, EWSED06, EWSED07, and EWSED09.

14.2.8.2.3 Toxicity Results

Tables 50 (Summary of Toxicity Testing for Soil and Sediment) and 49 (Summary of Results for Wetland Sediment) include a summary of the wetland sediment toxicity testing (bioassay) results. For the polychaete, *Neanthes arenaceodentata*, and the amphipod, *Leptocheirus plumulosus*, there were no statistically significant differences between the seven (7) Site samples and the two (2) reference samples for the survival or growth endpoints. Insufficient offspring were produced for a statistical analysis of the reproduction endpoint for amphipods.

The results of the toxicity study did not consistently correlate well with the results of the analytical chemistry. These results serve to illustrate the fact that toxicity test organism responses reflect exposure to the full balance of potential stressors, not individual COPECs. These stressors include Site COPECs and other types of stressors (*e.g.*, elevated salinities) that can exert independent and collective effects. Thus, caution should be exercised when interpreting such data regarding the co-occurrence of screening benchmarks.

14.2.8.3 Intracoastal Waterway Sediment

There were five (5) Site and two (2) reference area samples collected, as shown on Figures 64 (Intracoastal Waterway Sediment Sample Locations) and 65 (Intracoastal Waterway Reference Sediment Sample Locations), respectively. The sediment samples were collected from the 0 to 0.5 foot depth. There was not a formal assessment of benthic invertebrates in the samples during the field event; however, benthic invertebrates were observed in all of the Intracoastal Waterway sediment samples, including the reference samples. The most abundant organisms appeared to be polychaete worms (*Neanthes spp*.). Additionally, mud crabs and snapping shrimp were observed by the field crew in some of the sediment samples. Sediment pore water was extracted from all seven (7) locations and analyzed for Site COPECs. The COPECs for the Intracoastal Waterway bulk sediment and pore-water include 4,4'-DDT; acenaphthene; benzo(a)anthracene; chrysene; dibenz(a,h)anthracene; fluoranthene; fluorene; hexachlorobenzene; phenanthrene; and pyrene.

14.2.8.3.1 Ecological Setting

The benthic communities found in the Intracoastal Waterway and Oyster Creek in the Site vicinity are very similar to the communities that would be found in a primary or secondary bay on the Texas Gulf Coast. The Intracoastal Waterway represents a diverse ecological system. However, water depths, vehicle traffic, reduced light penetration, and higher than normal tidal energy prevent submerged vegetation from growing in the Intracoastal Waterway near the Site. The absence of attached vegetation that provides food and shelter decreases the number of invertebrate species that can utilize the habitat. Most of the epibenthic invertebrates that utilize the subtidal zone in the Intracoastal Waterway are migrants. In areas where tidal energy is reduced, sediment and organic detritus can accumulate and create a habitat for benthic infauna. A summary of potential ecological receptors typically present in Texas bay systems is presented below. These species may or may not be present in the Intracoastal Waterway in the vicinity of the Site.

The most common invertebrates in the subtidal zone are the micro- and macroinfauna. Microinfauna includes bacteria, flagellates, diatoms, and small worms and may represent a significant portion of the infaunal biomass. The macroinfauna (> 0.5 mm) include polychaete worms, copepods, gastropods, amphipods, and isopods. Parchment worms (*Chaetopterus variopedatus*) and lugworms (*Arenicola cristata*) are tube-dwelling polychaete worms that are common in the subtidal sediment. Other polychaete worms are *Eteone heteropoda*, *Laeonereis culveri*, *Neanthes succinea*, *Ceratonereis irritabilis*, and *Capitella capitata*. *E. heteropoda* and *C. capitata* are deposit feeders. The other polychaetes are active predators and feed on other invertebrates.

Bivalves and gastropods are also commonly abundant on the subtidal bottom. Most live in the sediment and communicate with the overlying water through a siphon. Burrowing bivalves that are common in muddy sediment are the stout razor (*Tagelus plebeius*), jackknife clam (*Ensis minor*), and angelwing (*Crytopleura costata*). Other bivalves that occur in the shallow subtidal zone are the constricted macoma (*Macoma constricta*), dwarf surf clam (*Mulinia lateralis*, also known as the coot clam), and southern quahog (*Mercenaria campechiensis*). The coot clam is a prolific member of the mud bottom community and serves as an important food source for diving ducks, shorebirds, and crabs.

Gastropods that may live on shallow subtidal bottom are the predatory whelks (*Busycon spiratum* and *Busycon contrarium*). The bubble shell (*Bulla striata*), virgin nerite (*Neritina virginea*), and mud snail (*Nassarius vibex*) are also found on shallow mud bottoms.

The most common large invertebrates typically present on the subtidal bottom are adult blue crabs (*Callinectes sapidus*) and penaeid shrimp. Blue crabs are good swimmers and are highly mobile, but will burrow into soft mud when shelter is not available. They are omnivorous scavengers that selectively feed on organic particles and soft-bodied invertebrates. Adult white shrimp (*Litopenaeus setiferus*) and brown shrimp (*Farfantepenaeus aztecus*) can be seasonally abundant on the subtidal bottom. They are omnivorous scavengers and grazers that feed on algae and organic detritus that accumulate as a flocculent in the upper centimeter of sediment.

14.2.8.3.2 Analytical Chemistry Results

Table 54 (Summary of Results of Intracoastal Waterway Sediment) provides a summary of the Intracoastal Waterway sediment data used in the original gradient determination and the Intracoastal Waterway sediment analytical results generated from the BERA sampling. Table 54 also compares the TCEQ's marine sediment benchmarks and marine surface water benchmarks to the 2010 BERA bulk sediment and pore-water data, respectively. Analytical results from the 2010 BERA sampling of Intracoastal Waterway sediment and associated reference sediment are presented in Figures 64 (Intracoastal Waterway Sediment Sample Locations) and 65 (Intracoastal Waterway Reference Sediment Sample Locations), respectively.

In general, the 2010 analytical results for Intracoastal Waterway sediments were lower than the analytical results from the RI data collected in 2008. There were no exceedances of the marine surface water benchmarks in sediment pore-water. The only exceedances of sediment benchmarks were in sample EIWSED02 for 4,4'-DDT; acenaphthene; and fluorene. As shown on Table 54, concentration gradients were identified for the majority of Site COPECs.

14.2.8.3.3 Toxicity Results

Table 54 includes a summary of the Intracoastal Waterway sediment toxicity testing (bioassay) results. For the polychaete, *Neanthes arenaceodentata*, and the amphipod

Leptocheirus plumulosus, there were no statistically significant differences between the five (5) Site samples and the two (2) reference samples for the survival or growth endpoints. Insufficient offspring were produced for a statistical analysis of reproduction for the amphipod. The results of the toxicity study did not consistently correlate well with the results of the analytical chemistry.

14.2.8.4 Surface Water

Wetland and pond surface waters were evaluated through the collection and analysis of three (3) samples from the Site as shown on Figure 66 (Wetland Surface Water Sample Locations). Surface water was not available at reference location EWSW02 (Figure 66). In general, surface water in the wetland area was not consistently present, and when present becomes highly saline as it rapidly evaporates. Surface water salinities measured for EWSW01, EWSW03, and EWSW04 were 43‰, 27‰, and 42‰, respectively (Table 47 – Field Sampling Parameters – Water). These salinities were consistent with salinities measured in the laboratory which were approximately 40‰, 30%, and 39‰ for EWSW01, EWSW03, and EWSW04, respectively. The COPECs for the surface water samples were location-specific. For EWSW01, the COPECs consisted of total acrolein and dissolved copper. The COPEC for EWSW03 was dissolved copper, and the COPEC for EWSW04 was dissolved silver. The original risk question that addressed the abundance, diversity, productivity, and function of the fish community is not applicable because of the harsh conditions and intermittent presence of the surface water in a salt panne. However, the 48-hour toxicity tests, using the brine shrimp as a test species, address any potential toxicity to water column invertebrates that may inhabit the intermittent ponds.

14.2.8.4.1 Ecological Setting

The wetlands area is indicative of marsh flats, which contain shallow pools and salt pannes. A salt panne is periodically flooded by tidal events that bring fresh sea-borne nutrients, small fish, and invertebrates. Salty brine remains when these shallow pools evaporate. These areas in the wetlands often dry out completely, creating even harsher conditions. When the seawater evaporates, the salts remain and accumulate over many tidal cycles. The difficult environs of the salt panne usually have soils that are frequently waterlogged, making them devoid of oxygen. The high salt concentrations, waterlogged soils, and warm waters associated with salt pannes mean that not many plants can survive and the biological diversity is low. The surface water samples were taken from these shallow pools with elevated salinity.

14.2.8.4.2 Analytical Chemistry Results

Table 55 (Summary of Results for Wetland Surface Water) provides a summary of the wetland surface water results considered in the original gradient determination and the wetland surface water analytical results generated from the BERA sampling. Analytical results from the 2010 sampling of wetland surface water are also presented in Figure 66 (Wetland Surface Water Sample Locations). The reference location EWSW02 was dry and could not be sampled for surface water. Because these pools are intermittent, acute surface water criteria were used for comparison. There were no exceedances of surface water acute criteria in any of the samples.

14.2.8.4.3 Toxicity Results

There is considerable uncertainty with the surface water toxicity test using the test species *Artmeia*. The test was run three times for a duration of 96 hours; however, the results were not reproducible between the three tests for the three samples. It was decided that the toxicity testing would be presented based on the results at 48 hours.

EWSW-01 showed acceptable laboratory control survival for tests one (100%) and 3 (90%) at 48 hours with no indication of toxicity from the Site surface water at any dilution (survival ranged from 80% - 100%).

EWSW03 showed acceptable laboratory control for tests 1 (100%) and 3 (94%) at 48 hours with no indication of toxicity from the Site surface water at any dilution (survival ranged from 98% - 100%) in test 1, but low survival in test 3 in all of the test dilutions (0% to 70%). It is unknown why the outcomes of the two tests were inconsistent.

EWSW04 showed acceptable laboratory control for test 1 (99%), but only 86% for test 3 at 48 hours. There was no indication of toxicity from the Site surface water at any dilution (survival ranged from 98% - 100%) in test 1. Survival in test 3 ranged from 82% to 98%.

14.2.9 Risk Characterization – Risk Estimation and Risk Description (Step 7)

The data collected to support the BERA were designed to address the ecological risk questions first presented in the Final BERA Work Plan and SAP:

1. Does exposure to COPECs in soil adversely affect the abundance, diversity, productivity, and function of the soil invertebrate community?

2. Does exposure to COPECs in bulk sediment and pore-water adversely affect the abundance, diversity, productivity, and function of the benthic invertebrate community?

3. Does exposure to COPECs in surface water adversely affect the abundance, diversity, productivity, and function of the fish community?

Overall, the data met the data quality objectives identified in the Final BERA Work Plan and SAP, and are adequate for evaluation and risk characterization in the BERA. However, the assumption presented in the Final BERA Work Plan and SAP that any impacts on toxicity would be solely due to Site COPECs proved to be incorrect. Similar inconsistent and modest toxicity was associated with soils/sediments from both the reference locations and the Site locations.

14.2.9.1 North Area Soils

The toxicity testing of *Neanthes arenaceodentata* over a 21-day exposure period showed no statistically significant differences between the North Area soil samples and the reference location soil samples. As summarized on Table 50 (Summary of Toxicity Testing for Soil and Sediment) and Table 51 (Summary of Results for North Area Soil), mean survival in the six (6) Site samples ranged from 76% to 96% and mean survival in the three (3) reference samples ranged from 60% to 92%. The growth data showed a similar relationship between the Site and reference samples. The results of the toxicity study did not always correlate well with the results of the analytical chemistry as compared to screening benchmarks.

The BERA concludes that there are no Site-related adverse effects when comparing the North Area samples to the reference samples and that exposure to COPECs in the North Area soil does not adversely affect the abundance, diversity, productivity, and function of the sediment invertebrate community. Note that the original risk question was directed to soil invertebrates (*i.e.*, earthworms), but through the BERA process it was determined that the habitat is not conducive to earthworms and is more applicable to saline tolerant sediment invertebrates.

14.2.9.2 Wetland Sediments

Toxicity testing of the wetland sediments was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus*. Tables 50 (Summary of Toxicity Testing for Soil and Sediment) and 49 (Summary of Results for Wetland Sediment) summarize the toxicity test results for these samples. There were no statistically significant differences between the Site wetland sediment samples and the reference wetland sediment samples. The comparison of bulk sediment and sediment pore-water concentrations to screening benchmarks (Table 49) generally indicates a relatively low bioavailability and low potential for sediment toxicity. The SEM/AVS ratios presented in Table 53 (Summary of AVS, SEM and Organic Carbon-Normalized Excess SEM Data for Wetland Sediment) are all above 1.0, except for EWSED08 with an SEM/AVS ratio of 0.157, which indicates that the potential exists for metal toxicity since sufficient AVS to completely form insoluble metal sulfides is not present. However, sediment organic carbon can also bind the free metals and reduce their availability to aquatic organisms. The ratio of “excess” SEM to the fraction organic carbon content of sediment was below 130 $\mu mol/g_{oc}$, the concentration predicted to be non-toxic by the

EPA, for six (6) of seven (7) Site samples. Also, the remaining Site sample (EWSED06) had an organic carbon-normalized excess SEM ratio of 168, which is at the low end of the range where the prediction of toxicity is uncertain (130 to 3,000 $\mu mol/g_{oc}$).

Because the results did not point to any single chemical stressor or physical parameter as the cause of any toxicity, further statistical analysis was conducted. Multiple linear regression (MLR), a form of multivariate statistical analysis, was selected to explore potential associations or dependencies between the various physical and chemical parameters (*i.e.*, the independent variables) and the toxicity test endpoints (*i.e.*, the dependent variables). "Associations," rather than "correlations" is the preferred term for the results of a multiple linear regression. An analysis of variance test that provides a correlation coefficient is a different statistical technique. Association does not prove causality, but causality cannot exist without association. The physical parameters evaluated in the MLR analysis included the sediment grain size percentages. The chemical parameters evaluated included total organic carbon (TOC), results of the AVS-SEM analysis, and the Site COPECs. The MLR analysis did not find any significant associations between PAHs and most metals for either toxicity test endpoint for either sediment test species.

Overall, the results of the MLR analysis indicate that some of the physical and chemical parameters, when considered individually or together in certain subsets, have statistically significant associations with the two toxicity test endpoints (*i.e.*, survival and growth). Zinc concentration indicated a statistically significant negative association, indicating a potential effect, and TOC indicated a statistically significant positive association with growth, but not percent survival, when regressed individually for *Leptocheirus plumulosus*. However, the adjusted correlation coefficients for these instances are low (*i.e.*, 50% or less) indicating weak correlations. Neither zinc nor TOC indicated statistically significant associations with growth, as measured by dry weight, or percent survival for *Neanthes arenaceodentata*. Therefore, only one of four possible outcomes indicated statistically significant associations.

A regression subset with statistically significant associations to survival for *Neanthes arenaceodentata* included TOC (positive) and percent medium gravel (positive). Similarly, the subset of TOC (positive), copper SEM concentration (negative), lead SEM concentration (positive), nickel SEM concentration (negative), and the sum of SEM metals' concentrations divided by the AVS concentration (negative) indicated statistically significant associations to dry weight for *Leptocheirus plumulosus*. A regression subset with statistically significant associations to survival for *Neanthes arenaceodentata* included percent clay (negative), percent fine gravel (negative), percent coarse sand (positive), percent fine sand (negative), and percent medium sand (negative).

These conclusions are somewhat confounded by the fact that no parameter's individual statistically significant association is ever true for both endpoints for the same organism or both organisms. These results may be related to the small number of dependent variables (*i.e.*, nine values per toxicity test endpoint) that creates a weakness of the MLR analysis.

The risk characterization results conclude that mortality and decreased growth of surviving organisms observed in the wetland sediment toxicity tests cannot be attributed to any one physical and/or chemical parameter. Considering the results as a whole, it is possible that a combination of parameters, such as TOC, certain sediment grain sizes, and contaminants (either inorganic or anthropogenically organic) may have influenced the pattern and degree of mortality of *Leptocheirus plumulosus* across all Site and reference location wetland sediment samples. Ultimately, the BERA concludes that there are no Site-related adverse effects when comparing the Site wetland area samples to the reference wetland sediment samples, and that exposure to COPECs in bulk sediment and pore-water does not adversely affect the abundance, diversity, productivity, and function of the benthic invertebrate community.

14.2.9.3 Intracoastal Waterway Sediments

Toxicity testing of the Intracoastal Waterway sediment was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus*. Table 50 (Summary of Toxicity Testing for Soil and Sediment) and Table 54 (Summary of Results of Intracoastal Waterway Sediment) summarize the toxicity test results for these samples. There were no statistically significant differences between the Site Intracoastal Waterway sediment samples and the reference location Intracoastal Waterway samples. The comparison of bulk sediment and sediment pore-water concentrations to screening benchmarks (Table 54) indicates a low potential for sediment toxicity.

The BERA concludes that there are no Site-related adverse effects when comparing the Site Intracoastal Waterway samples to the reference Intracoastal Waterway samples and that exposure to COPECs in bulk sediment and pore-water does not adversely affect the abundance, diversity, productivity, and function of the benthic invertebrate community.

14.2.9.4 Surface Water

Only three (3) of the four (4) scheduled surface water samples from the wetland area were collected, and the wetland area sampled can be categorized as a salt panne, with limited ecological resources. There were no exceedances of the surface water acute criteria for the COPECs acrolein, copper, or silver (Table 55 – Summary of Results for Wetland Surface Water), and the toxicity tests were no acutely toxic at a 48-hour test duration. The original risk question that addressed the abundance, diversity, productivity, and function of the fish community is not applicable because of the harsh conditions and intermittent nature of the surface water in a salt panne; however, the 48-hour toxicity tests using the brine shrimp as a test species indicates a low potential for toxicity from exposure to surface water.

14.2.10 Uncertainty Analyses (Step 7 Continued)

Uncertainties are associated with each step in the BERA process, including problem formulation, ecological effects evaluation, exposure estimation, and risk characterization. According to the EPA, uncertainty should be distinguished from variability, which arises from true heterogeneity or variation in the characteristics of the environment and receptors. The interpretation of the BERA results are aided by a recognition and understanding of the source and nature of the known set of uncertainties that can influence the risk characterization results.

14.2.10.1 Uncertainties in Problem Formulation

Potential uncertainties associated with the problem formulation phase of the BERA are related to the identification of COPECs, contaminant fate and transport, and exposure pathways.

14.2.10.1.1 COPEC Selection

The BERA COPECs were identified using data obtained from the RI. These COPECs and others were identified as those with a potential to cause adverse effects as described in the Final SLERA. Elimination of certain COPECs during the SLERA streamlined the focus of the BERA to the COPECs that required additional investigation. Uncertainty may be associated with the environmental sampling for the RI and the BERA. Uncertainty may also be associated with the laboratory analysis of the Site samples, but there are a number of quality control and quality assurance measures that minimize errors and uncertainty.

It is believed that uncertainty associated with COPEC selection for the BERA is minimal since: 1) the SLERA process is, by design, conservative to avoid underestimating potential risk by inadvertently eliminating any COPECs, and 2) COPECs evaluated in the BERA were the more relatively toxic and prevalent compounds, both in frequency and concentration, at the Site. Furthermore, if the presence of a chemical were responsible for decreased survivorship and growth, a statistical difference would have been more apparent between Site and reference samples, unless the compound(s) was present at both Site and reference sampling locations at similar concentrations.

14.2.10.1.2 COPEC Gradient

The 2010 sampling locations were chosen based upon the RI data obtained between 2006 and 2008. Between the RI sampling in 2006-2008 and the BERA sampling in 2010, there has been periodic flooding, in addition to the landfall of Hurricane Ike in September 2008. The potential impacts of these events on COPEC concentrations is unknown; however, the COPEC concentrations in BERA samples were generally less than COPEC concentrations in RI samples. If COPEC concentrations across the Site uniformly decreased because of flooding events, then the BERA sample locations based on RI data are equally representative of Site conditions, as if the locations had been randomly chosen. There is potential uncertainty in the true representativeness of the BERA COPEC concentrations, but it is considered to be minimal. The

COPEC concentrations gradients are shown on Tables 51 (Summary of Results for North Area Soil), 51 (Summary of Results for Wetland Sediment), and 54 (Summary of Results of Intracoastal Waterway Sediment). The COPECs are adequately represented as being present at high, medium, and low concentrations in relation to one another (*i.e.*, a high concentration is the highest of the detected concentrations) but may not be considered high when compared to a benchmark. The presence of the concentration gradients meets the study objectives and there is little uncertainty associated with the presence of the concentration gradients for the COPECs.

14.2.10.1.3 Reference Sample Location Selection

Sediment reference locations were chosen as part of the initial investigation, during the RI field work, prior to the initiation of the ecological risk assessment activities. As recommended by the EPA's guidance, the ideal background reference areas should have the same physical, chemical, geological, and biological characteristics as the site being investigated, but without being affected by activities on the site. The reference areas were purposefully chosen out of the area of the Site's influence, but in areas that were grossly similar to the Site. There were no visible signs of disturbance, impact, or debris at any of the reference areas.

The reference locations are in the proximity of the Site where they are similarly influenced by storm surges and rain events, but are not so close in proximity to be influenced by site activities, as evidenced by data collected during the RI. The reference locations for the wetland sediment, North Area soils, and Intracoastal Waterway are considered appropriate and valid as an "ideal" background reference area as demonstrated by the low detections of chemicals, and similar physical and chemical characteristics. As such, there is little uncertainty associated with using the reference samples for comparison to Site samples in the BERA.

14.2.10.2 Uncertainties, Exposure Analysis/Ecological Effects Evaluation

The following section discusses the uncertainties in the exposure analysis and ecological effects evaluation phases of the BERA. Exposure can be expressed as the co-occurrence or contact of the stressor with the ecological components, both in time and space. Uncertainties in the exposure analysis phase are centered on the quantification of the magnitude and patterns of exposure as they relate to the risk questions developed in the problem formulation phase. For this BERA, Site-specific exposure response information was obtained by evaluating measurements of direct toxicity by multiple lines of evidence. The potential for confounding stressors that might influence the exposure response in the toxicity tests are discussed in this section of the ROD.

14.2.10.2.1 Bioavailability

The uncertainty of the amount of the COPEC that is bioavailable to the ecological receptors is minimized in this BERA through the use of the whole-sediment toxicity testing. The placement of the test organisms into the sediment creates an exposure potential that mimics the environment. Additionally, the sampling of pore-water presents an additional line of evidence for bioavailability potential. When the Site pore-water concentrations are compared to chronic surface water criteria, there were a few exceedances (*e.g.*, endrin aldehyde in the pore-water from the wetland sediment); however, these exceedances do not correlate with toxicity, especially when considering the similar results from the Intracoastal Waterway toxicity tests with no exceedances of marine surface water criteria compared to the pore water. This indicates that the bioavailable fraction of the chemicals is not a unique or significant contributor to toxicity in the Site or reference locations from either the Intracoastal Waterway or the wetlands sediments.

14.2.10.2.2 Synergistic or Antagonistic Effects of Constituents

Some constituents will vary in toxicity depending on the presence of other constituents, either by increasing absorption, uptake, or toxicity (synergistic), or by decreasing absorption, uptake, or toxicity (antagonistic). The relationships between constituents are poorly understood, except for the select few that have been studied. In addition to constituent interactions, other environmental factors (*i.e.*, TOC, sulfide, pH, conductivity, etc.) can either increase or decrease the absorption, uptake, or toxicity of a constituent. The magnitude of these uncertainties is unknown for most constituents.

14.2.10.2.3 Naturally Occurring Organisms

The possibility that naturally-occurring benthic invertebrates might have influenced the test organisms through predation or competition for food is unlikely. Records document that no invertebrates other than the test organisms were observed in the samples after test termination. Additionally, all of the samples were press-sieved, thereby likely eliminating predators, except for the heavy clay North Area soils that were hydrated for the 21-day polychaete test.

14.2.10.2.4 Laboratory Control Organisms

The uncertainties associated with the performance of the laboratory controls are minimal. All of the laboratory controls showed acceptable survival and growth. The average survival of *Neanthes arenaceodentata* in the controls ranged from 96% to 100%, whereas the average survival of *Leptocheirus plumulosus* in the controls was 81.5%. These results indicate that *Leptocheirus plumulosus* was more sensitive than *Neanthes arenaceodentata* to test conditions even in an optimal control medium.

14.2.10.2.5 Test Species

Two species were ultimately used in the sediment and soil toxicity testing (*Leptocheirus plumulosus* and *Neanthes arenaceodentata*) and one species was chosen for the surface water testing (*Artemia salina*). The choice of a test organism has a major influence on the relevance, success, and interpretation of a test. Ideally, a test organism for use in tests should have: 1) a toxicological database demonstrating relative sensitivity to a range of contaminants of interest; 2) be in direct contact with the medium of interest; 3) be readily available from culture; 4) be easily maintained in the laboratory; 5) have a broad geographical distribution, be indigenous to the site being evaluated, or have a niche similar to the organisms of concern (*e.g.*, similar feeding guild or behavior to the indigenous organisms); 6) be tolerant of a broad range of physico-chemical characteristics (*e.g.*, grain size); and 7) be compatible with exposure methods and endpoints.

Amphipods like *Leptocheirus plumulosus* have been used extensively to test the toxicity of marine, estuarine, and freshwater sediments. *Leptocheirus plumulosus* is an infaunal amphipod intimately associated with sediment, due to its burrowing and sediment ingesting nature. *Leptocheirus plumulosus* is found in both oligohaline (0.5-5 ‰) and mesohaline (5-18 ‰) regions of estuaries on the East Coast of the U.S and is tolerant to a wide range of sediment grain size distribution. There is uncertainty with using *Leptocheirus plumulosus* in the toxicity testing at the Site because it is not native to the area and generally prefers a less saline environment. The salinities from the Site ranged from 27 to 43 ‰. In general, the amphipod *Leptocheirus plumulosus* did not perform as well in the reference samples or laboratory control samples as the polychaete worm *Neanthes arenaceodentata*. The mean survival for *Leptocheirus plumulosus* in the laboratory controls was 81.5%, whereas the mean survival for *Neanthes arenaceodentata* in the laboratory controls was 100% and 96%. These results may indicate that *Leptocheirus plumulosus* is a more sensitive test organism than *Neanthes arenaceodentata*.

Neanthes sp. were noted as present in the Intracoastal Waterway sediments during field collection, indicating that this genus is indigenous to the area. *Neanthes arenaceodentata* has been documented as a reliable test organism, especially for the sublethal effect of growth in marine sediment bioassays. Toxicity tests using *Neanthes arenaceodentata* were conducted at two exposure durations of 28 days and 21 days. The use of *Neanthes arenaceodentata* as a test organism is associated with little uncertainty in the BERA.

The BERA Work Plan and SAP proposed the use of mysid shrimp as the test species, but when the surface waters were received at the laboratory the measured salinities were elevated beyond a level appropriate for the mysid shrimp. *Artemia salina* has an extreme euryhaline character. Its tolerance to salinity ranges from brackish water to saturated brines and therefore was a logical choice as an alternate test organism for the highly saline surface waters at the Site. The performance of *Artema salina* as a test organism proved to be uncertain. The performances of the three tests were not consistent or reproducible. The ultimate conclusions of the surface water assessment is that the concentrations of the COPECs in the surface water were all less than acute criteria and the validity of the test at a 48-hour exposure was relatively stable between test runs.

14.2.10.3 Uncertainties in Risk Characterization

Risk characterization is the final phase of the BERA and includes two major components, risk estimation and risk description. Risk estimation consists of integrating the exposure profiles with the exposure effects information and summarizing the associated uncertainties. The risk description provides information important for interpreting the risk results.

14.2.10.3.1 Comparison of Site Samples to Reference Locations

Because the reference samples were selected to be as identical as possible to the Site samples (minus the presence of Site-related constituents) in regards to ecosystems, physical setting, and water chemistry, comparing the reference locations to the Site samples imparts minimal uncertainty when evaluating the toxicity testing results. The magnitude of the uncertainty and influence on the BERA risk management conclusions is, therefore, expected to be minimal. Reference locations were utilized in the BERA for the study areas and media. The purpose of the reference samples was to be able to distinguish toxicity effects that would occur without the presence of the Site COPECs as defined by the SLERA. All of the results for the analytical chemistry and toxicity endpoints in Site samples should be considered in relation to the results from the reference samples.

Both of natural processes and anthropogenic processes could result in the presence of various stressors not associated with the Site. Natural processes include deposition of naturally-occurring metallic minerals in sediments (*e.g.*, silicon, calcium, sodium, potassium, phosphorus, carbonates, or sulfates). Anthropogenic processes include deposition of chemicals from internal combustion engine exhaust, dredge spoil, mosquito spraying, highway runoff, and flood events. Marine engines have limited emissions controls for air emissions and no controls for particulate matter and their emissions are therefore similar to what would be found on a busy highway.

14.2.10.3.2 Correlation of Toxicity Results with Other Factors

The results of the toxicity studies are not always well correlated to the results of the analytical chemistry when compared to benchmarks. For example, while reference concentrations of barium and zinc are elevated in soil sample NAS07, the mean survival of *Neanthes arenaceodentata* in that sample was high (92%). Contrastingly, reference concentrations of all metal COPECs are below the TCEQ’s soil benchmarks for soil sample NAS09, yet this sample evidenced the highest toxicity (60% mean survival). This lack of correlation is not surprising given the many variables associated with site-specific toxicity testing when compared with benchmark values, which are derived using various methods and data sets.

14.2.10.3.3 Artemia Testing

The surface water toxicity tests were run at a 96-hour duration, but there is uncertainty with the application of the 96-hour time frame for the evaluation of brine shrimp (*Artemia salina*). Test methods using *Artemia* are for 24- to 48-hour exposures. The exposure period of 24 hours is usually associated with the testing of freshly hatched individuals. For the surface water toxicity testing completed for the Site, control failure did not occur at 24 hours, for all three (3) test runs, or at 48 hours, from test runs 1 and 3 for samples EWSW01 and EWSW03. Sample EWSW04 in test 3 had an 86% survival for the control at 48 hours, but survival of *Artemia* in the Site surface water ranged from 82% to 98%. The 100% surface water samples (*i.e.*, undiluted) for EWSW-01 and EWSW-04 exhibited survival rates of 97% and 99% in the first test, respectively, and 80% and 96% in the third test, respectively, after 48 hours, indicating consistency in the tests. Conversely, the 100% surface water sample (*i.e.*, undiluted) for EWSW-03 exhibited survival rates of 100% and 0% in the first and third tests, respectively. The inconsistencies in the test results are likely due to the unreliability of *Artemia* as a test organism for tests of greater than 48 hours duration.

14.2.10.3.4 Toxicity Testing Duration

Ten-day tests are designed to be acute exposure tests for higher concentrations of toxic chemical compounds. Twenty eight-day tests are designed to be chronic exposure tests for lower concentrations of toxic chemical compounds to detect sublethal effects. The chronic exposure tests were selected as being the best measure of Site conditions and potential toxicity from sediment samples for the Site.

If the conclusion is that the Site COPECs are not the cause of mortality and decreased dry weight in the 28-day tests, then it follows that the COPECs would not be responsible for any observed adverse effects related to the COPECs in a proposed 10-day test. Sublethal and lethal effects caused by physical parameters (*i.e.*, sediment composition) of the sediment samples would likely be less evident in the shorter test. Adverse effects, unless acute in nature, take time to become manifest and measurable, whether related to chemical presence or physical attributes (*e.g.*, sediment grain size composition) in the organism’s environment. The longer the bioassay test, the more exposure and the more time there is for the adverse effect, be it slowed growth, delayed reproduction, or early death, to appear and be measured. Thus, the likely outcome of a shorter-duration test would be higher survival percentages and lower dry weight values (due to the shorter exposure time and lessened opportunity to feed and grow) among the replicates for both Site samples and reference location samples.

Various studies were found in the literature to support the notion that variability in toxicity testing results may be greater for chronic exposures, but toxic effects are likely to become more evident. In one study with a different amphipod species, short-term survival was not affected by large variations in sediment grain size but was correlated to growth in the 28-day exposure. Additionally, survival was much lower in the longer-term study, even for the uncontaminated reference site and the least contaminated site. The results for these two sites also evidenced greater variability in the 28-day study as opposed to the 10-day study. Growth was not measured in the 10-day exposure tests, nor was reburial measured in the 28-day tests.

An EPA guidance document on the method for chronic toxicity testing of sediments using the same amphipod species notes several studies that evaluated the comparative sensitivity between the acute and chronic tests. A study noted that the reproductive endpoint of the chronic test was more sensitive than the survival and growth endpoints of the acute and chronic tests. However, another study found the sublethal endpoints to be less sensitive than the survival endpoint.

14.2.11 Risk Management (Step 8)

Risk management is a distinctly different process from risk assessment. The risk assessment establishes whether a risk is present and defines a range or magnitude of the risk (EPA 1997). For this BERA, the risk characterization determined that there is no difference in the toxicity observed in samples collected at the reference locations and the Site for sediment and soil exposure, and that there was no toxicity associated with surface water. Because of the lack of Site-related toxicity, development of ecologically-based remediation goals was not necessary.

14.2.12 Conclusions of the Ecological Risk Assessment

Toxicity testing of sediment was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus* using the wetland sediments and Intracoastal Waterway sediments. A 21-day whole-sediment/soil toxicity test using *Neanthes arenaceodentata* was applied to the North Area soils. The bioassays for the surface water were conducted on brine shrimp (*Artemia salina*) and assessed at a 48-hour duration. Sample locations were chosen based on a concentration gradient of the COPECs of ecological concern identified in the SLERA.

The analysis of the toxicity and analytical data for all of the sediment areas that were sampled showed that the most relevant comparison was of Site sample results to reference location sample results. This enables the comparison of results between Site samples and those reference samples that exhibit similar environmental conditions, but are not influenced by releases from the Site. Ultimately, it was determined that there is no difference in the toxicity observed in samples collected at the reference locations and the Site for sediment and soil exposure and that there was no toxicity associated with surface water. Because of the lack of Site-related toxicity, development of ecologically-based remediation goals was not necessary.

14.3 Basis for Remedial Action

The Selected Remedy and remedial action described in this ROD are necessary to protect the public health or welfare or the environment from actual releases of hazardous substances into the environment. The human health and ecological risk assessments concluded that current or potential future Site conditions pose no unacceptable risks to human health or to the environment, respectively, except for human exposure to VOCs in any future buildings, at the North Area, at levels posing an unacceptable risk for commercial/industrial workers via the ground water to indoor air pathway. In reaching this conclusion, the risk assessments assumed the continuing effectiveness of the cap, continuing restriction of land use at the Site to commercial/industrial land use, and that the Site ground water would not be used.

15.0 REMEDIAL ACTION OBJECTIVES

Remedial Action Objectives (RAOs) consist of medium-specific goals for protecting human health and the environment. As such, RAOs are developed for those exposure pathways identified as posing an unacceptable risk to either: (1) human receptors as described in the BHHRA, and/or (2) ecological receptors based on data developed in the BERA. The RAOs developed for the Site are: 1) prevent further migration of the VOC and SVOC plumes in Zones A and B, both in terms of lateral extent and the absence of impacts above screening levels to underlying GWBUs; 2) to prevent human exposure to VOCs in any future buildings at levels posing an unacceptable risk for commercial/industrial workers via the ground water to indoor air pathway; 3) to prevent land use other than commercial or industrial; 4) to prevent ground water use; and 5) to prevent potential future exposure to remaining waste material in the former surface impoundments.

The EPA's Selected Remedy identified in this ROD will meet these RAOs. Based on data presented in the Final BERA Report, no RAOs were developed based on ecological endpoints given the lack of potential risk to these receptors. As such, RAOs for the Site were identified to address concerns or risks related to future human health exposure mainly associated with North Area ground water and the former surface impoundments.

15.1 Basis and Rationale for the Remedial Action Objectives

The basis for the RAOs for the Site is to ensure that current and future receptors are not exposed to ground water contaminated with VOCs and SVOCs through ingestion and inhalation of VOCs via the ground water to indoor air pathway and to ensure that the ground water plumes remain stable. The Final RI and BHHRA Reports note that ground water in affected water-bearing units at the Site (*i.e.*, Zones A and B) and the next underlying water-bearing unit (*i.e.*, Zone C) is not useable as a drinking water source due to naturally high TDS concentrations. Consequently, the only potentially unacceptable human health risks associated with COIs detected in Site ground water are for the pathway involving volatilization of VOCs from North Area ground water to a hypothetical indoor air receptor. This conclusion is based on the stability of the ground water plume, both in terms of lateral extent in Zones A and B and the absence of COIs in deeper water-bearing units.

The clay cap covers the former surface impoundments and prevents rainwater from infiltrating into the source area. If the cap was not present, or is not maintained in the future, then infiltration into the source area would increase and accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. The RAOs address the need to maintain the effectiveness of the Site cap, as well as the need to insure that the other assumptions made in the risk assessments – that Site land use would be restricted in the future to commercial/industrial land use and that Site ground water would not be used – would remain valid.

15.2 Risks Addressed by the Remedial Action Objectives

Potentially unacceptable human health risks associated with COIs detected in Site ground water for the pathway involving volatilization of VOCs from North Area ground water to a hypothetical indoor air receptor will be addressed by the RAOs for the Site. The BHHRA showed that there were no unacceptable cancer risks or noncancer hazard indices for any of the current or future exposure scenarios, except for future exposure to an indoor industrial worker if a building is constructed over impacted ground water in the North Area. Potential cancer risks in the North Area, using maximum shallow Zone A ground water concentrations and the J&E VIM model, were predicted to be greater than 1.0×10^{-4}, while the HIs were estimated to be greater than 1. Generally, the EPA considers a remedial action to be warranted at a site where the ELCR exceeds $1.0 \times 10^{\mathbf{-4}}$. The need for a remedial action for risks falling within the $1.0 \times 10^{\mathbf{-4}}$ to $1.0 \times 10^{\mathbf{-6}}$ range is judged on a case-by-case basis (unless applicable or relevant and appropriate requirements are exceeded). Risks less than $1.0 \times 10^{\mathbf{-6}}$ generally do not require a remedial action. The point of departure for evaluating ELCR for individual carcinogens is $1.0 \times 10^{\mathbf{-6}}$. An HQ or HI greater than 1 indicates some potential for adverse non-cancer health effects associated with the COCs for the Site.

Potential cancer risks in the North Area were predicted to be 2.0×10^{-2}, which is 200 times greater than the EPA's risk level of 1.0×10^{-4}. This means that for every 10,000 people that could be exposed 200 extra cancer cases may occur as a result of exposure to Site-related contaminants (*i.e.* VOCs) via the ground water to indoor air pathway. The HI was estimated to be 18.0 indicating that non-cancer health effects are possible via this pathway. It should be noted that this scenario was evaluated despite the current restrictive covenant on Lots 55, 56, and 57 that require future building design to preclude vapor intrusion, which would effectively make this pathway incomplete. Therefore, current risks at the Site are acceptable given the low levels of potential exposure. Estimated risks from Zone A ground water at the South Area were below the EPA's goals; therefore, adverse risks associated with the vapor intrusion pathway are unlikely in this area.

The clay cap covers the former surface impoundments and prevents rainwater from infiltrating into the source area. If the cap was not present, or is not maintained in the future, then infiltration into the source area will increase and accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. A conservative qualitative assessment determined that the undiluted concentrations of ground water COIs discharging into the waterway could pose a risk to contact recreation receptors. As an example, the maximum reported concentration for Zone A ground water of 292.0 mg/L for 1,2-DCA is more than three (3) orders of magnitude higher than the TRRP PCL of 0.196 mg/L. Another example shows that the maximum reported concentration for Zone A ground water of 234.0 mg/L for 1,1,1-TCA is almost five (5) times higher than the TRRP PCL of 47.2 mg/L. This conservative qualitative assessment shows that contact recreation receptors could be at risk, through ingestion and dermal contact, if the Zone A impacted ground water reached the Intracoastal Waterway's surface water and sediments.

16.0 DESCRIPTION OF ALTERNATIVES

A total of three remedial alternatives were developed for the Site in the Feasibility Study (FS, PBW 2011c). Alternative 2 (Ground Water Controls and Monitoring) is the Selected Remedy described in this ROD. The remedial alternatives described in this ROD were developed to address the RAOs and remedial goals, source control, containment, and restoration objectives for the Site. The NCP requires development of a range of alternatives that address principal threats posed by the Site, but that vary in the degree of treatment used and the quantities and characteristics of untreated wastes that must be managed. Alternatives were developed to address the RAOs within an acceptable time frame. To the maximum extent feasible, the alternatives minimize the need for long-term management. Alternative 1 (No Action), required by the NCP, has been retained as a baseline alternative against which the effectiveness of all other remedial alternatives are judged. The three remedial alternatives developed for the Site are:

1. Alternative 1 – No Action.
2. Alternative 2 – Ground Water Controls and Monitoring.
3. Alternative 3 – Ground Water Containment.

The ARARs applicable to the Site and the remedial alternatives presented in this ROD are listed in Table 1 (List of ARARs for Gulfco Marine Maintenance Superfund Site). ARARs are discussed in more detail in Section 20.2 (Compliance with Applicable or Relevant and Appropriate Requirements) of this ROD.

16.1 Common Elements of Each Remedial Alternative

ICs for the ground water, surface impoundments cap, ground water monitoring, O&M, and five-year reviews are common elements of each remedial alternative described in this ROD, except for Alternative 1 (No Action). These elements are discussed in the following sections of this ROD.

16.1.1 Institutional Controls

ICs are non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy. Although it is EPA's expectation that treatment or engineering controls will be used to address principal threat wastes and that ground water will be returned to its beneficial use whenever practicable, ICs play an important role in site remedies because they reduce exposure to contamination by limiting land or resource use and guide human behavior at a site. For instance, zoning restrictions prevent site land uses, like residential uses, that are not consistent with the level of cleanup. ICs are used when contamination is first discovered, when remedies are ongoing, and when residual contamination remains on-site at a level that does not allow for unrestricted use and unlimited exposure after cleanup. The NCP emphasizes that ICs are meant to supplement engineering controls.

ICs, such as restrictive covenants, would continue to be implemented at the Site under Alternatives 2 (Ground Water Controls and Monitoring) and 3 (Ground Water Containment). ICs for the ground water would be implemented to ensure that the ground water underlying the Site is not used for any purpose. Although the ground water is not potable, industrial use could occur in the future. The ICs for the South Area that prohibit land use other then commercial/industrial also would continue to be implemented. In addition, current ICs will be implemented to maintain protection against potential exposures to VOCs at levels posing an unacceptable risk via the ground water to indoor air pathway (*i.e.*, indoor vapor intrusion) for building construction on Lots 55, 56 and 57. Under both alternatives, the current restrictive covenants will be reviewed and evaluated to insure their protectiveness. In conjunction with the restrictive covenant review/evaluation component, it is anticipated that one or more modifications to the current ICs may be required. These modifications may include the addition of supplemental information regarding the type and location of hazardous substances at the Site, including the affected ground water plume, such as a metes and bounds description of the affected area and a list of the contaminants present, clarification of all use restrictions in accordance with the remedial action, and other changes as appropriate to reflect the requirements of Title 30 of the Texas Administrative Code, Section 350.111, and any applicable state and federal rules and statutes. The existing ICs also will be modified and/or supplemented to identify the location of the existing surface impoundments cap and restrict actions that might affect the integrity of the cap.

The owners of the Site will be responsible for implementing and maintaining these controls. The TCEQ will be responsible for enforcing these controls.

16.1.2 Surface Impoundments Cap

The existing surface impoundments cap will prevent rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. If the cap continues to be maintained and repaired, the EPA does not believe that the contaminated ground water plume will reach the Intracoastal Waterway's surface water and sediments given the limited extent of contaminant migration observed during the 27 to 38 years since operation and closure of the former surface impoundments and the low ground water velocity at the Site. The existence and maintenance of the surface impoundments cap, under Alternatives 2 (Ground Water Controls and Monitoring) and 3 (Ground Water Containment), will also eliminate a point of exposure and many of the routes of exposure; specifically, incidental ingestion and dermal contact for recreational swimmers as well as ingestion of seafood by subsistence and recreational fishermen. There would also be the potential for direct skin contact by future on-site workers and current potential youth trespassers through exposure to the contaminated material under the cap. Continued maintenance and repair of the cap addresses the RAO of preventing potential future exposure to remaining waste material in the former surface impoundments. If the cap were removed or not maintained, then these routes of exposure could lead to increased carcinogenic risks and non-carcinogenic health effects to these receptors.

16.1.3 Ground Water Monitoring

Ground water monitoring is appropriate at sites where the data is inconclusive or indicates minimal risk. At this Site, both Alternatives 2 and 3 address the RAO of preventing further migration of the VOC and SVOC plumes in the ground water in part by confirmation through monitoring that the plumes are not moving. Annual ground water monitoring would be implemented at the Site under each of the alternatives, except Alternative 1 (No Action), to evaluate the protectiveness of the Selected Remedy.

16.1.4 Operations and Maintenance

O&M of a remedy is required to ensure that the remedy performs as intended. Actions range from maintaining the surface impoundments cap to performing ground water monitoring. O&M would be implemented at the Site under each of the alternatives described in this ROD, except Alternative 1 (No Action).

16.1.5 Five-Year Reviews

Five-year reviews are required if a remedy results in hazardous substances remaining on-site above levels that allow for unlimited use and unrestricted exposure. These reviews would be conducted no less often than every five years after initiation of the remedial action to ensure that the remedy is, or will continue to be, protective of human health and the environment. Five-year reviews would be conducted at the Site under each of the alternatives described in this ROD, except Alternative 1 (No Action), since hazardous substances would remain on-site above levels that allow for unlimited use and unrestricted exposure.

16.2 Distinguishing Features of Each Remedial Alternative

Following is a discussion of the distinguishing features of the remedial alternatives and the remedial technologies to address the contamination in the Site ground water. The entire list of the remedial technologies considered for the remediation of the contamination in the impacted ground water can be found in the FS Report (PBW 2011c). In general, the list of technologies fit into one or more categories of General Response Actions (GRAs). GRAs are generic, medium-specific, remedial actions that will satisfy the RAOs for the Site. GRAs may possibly include no action, institutional controls, containment, removal, treatment, disposal, monitoring, or a combination thereof. The development of remedial alternatives begins with the identification of GRAs that can meet the RAOs for the Site, which are then screened and developed into remedial alternatives to address all contaminated media at the Site.

16.2.1 Alternative 1: No Action

Alternative 1 (No Action), consideration which is required by the NCP (§300.430[e][6]), is the baseline alternative against which the effectiveness of all other remedial alternatives are judged. Under this alternative, the EPA would take no action at the Site to prevent exposure to the contaminants remaining at the Site. Under this alternative, no remedy or ICs (beyond those currently in place) are implemented. Thus, the current restrictive covenants would continue to be implemented under this alternative, but no other actions would be taken. The current restrictive covenants include: (1) the prohibition of any land use other than commercial/industrial for all parcels on the Site; (2) the prohibition of any ground water use for all parcels on the Site; and (3) the requirement that any buildings on Lots 55, 56 and 57 be designed to preclude indoor vapor intrusion and that the EPA and TCEQ be notified prior to any building construction on these parcels.

16.2.2 Alternative 2: Ground Water Controls and Monitoring

Alternative 2 consists of the monitoring of the Site's ground water and the continued implementation of ICs. The total present worth cost, including contingencies, for this alternative is projected at $230,000. A cost evaluation of Alternative 2 is provided in Table 2 (Alternative 2 Preliminary Cost Projection), which includes key assumptions regarding monitoring program requirements.

Alternative 2 includes the following components:

1. Review and evaluation of the current restrictive covenants prohibiting ground water use at the Site and requiring commercial/industrial land use and protection against indoor vapor intrusion for building construction on Lots 55, 56, and 57;

2. Modification of the existing Institutional Controls (ICs) to address any issues identified with the current restrictive covenants after review, identify the type and location of hazardous substances, identify the location of the existing cap and restrict actions that might affect the integrity of the cap, and any other necessary modifications;

3. A cap over the former surface impoundments;

4. Annual ground water monitoring, and monitoring as a part of the Five-Year Reviews, to confirm stability of the affected ground water plume; and

5. Implementation of an Operation and Maintenance Plan to provide ground water monitoring and inspection/repair of the cap covering the former surface impoundments.

Following are the descriptions of the remedial components for Alternative 2 that address the Site ground water contamination in addition to the common components for Alternatives 2 and 3 described above.

16.2.2.1 Ground Water Monitoring Component

For the ground water monitoring component of Alternative 2, the stability of the affected ground water plume will be confirmed by an evaluation of the temporal trends of the primary ground water COIs which include 1,1,1-TCA; 1,1-DCE; 1,2,3-TCP; 1,2-DCA; benzene; cis-1,2-DCE; methylene chloride; PCE; TCE; and VC; above their respective extent evaluation criteria and their 1% compound solubility limit within the monitoring well network. Data from the monitoring well network will be used to demonstrate the occurrence of natural attenuation of the ground water plumes. The EPA's guidance document titled, "Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities, Unified Guidance" (March 2009, USEPA Office of Resource Conservation and Recovery, EPA 530-R-09-007) will be used in this evaluation.

16.2.3 Alternative 3: Ground Water Containment

Alternative 3 uses containment technologies to address the RAOs for the affected ground water. The total present worth cost, including contingencies, for this alternative is projected at $4,700,000. A cost evaluation of Alternative 3 is provided in Table 56 (Alternative 3 Preliminary Cost Projection), which includes key assumptions regarding ground water extraction/treatment rates and monitoring program requirements.

Alternative 3 includes the following components:

1) Review/evaluation of current restrictive covenants prohibiting ground water use at the Site and requiring industrial/commercial land use and protection against indoor vapor intrusion for building construction on Lots 55, 56, and 57;

2) A cap over the former surface impoundments;

3) Installation/operation of a series of vertical ground water extraction wells to provide hydraulic control of affected ground water and potentially to attempt to recover and treat the NAPL in the Site ground water;

4) Treatment of collected ground water using low profile aeration with off-gas treatment by catalytic oxidation;

5) Discharge of treated ground water to the City of Freeport publicly-owned treatment works (POTW) or to the Intracoastal Waterway through a Texas Pollutant Discharge Elimination System (TPDES) permitted outfall if discharge to the POTW is not feasible;

6) Annual ground water monitoring to verify the effectiveness of ground water hydraulic control; and

7) Implementation of an Operation and Maintenance Plan to provide inspection/repair of the cap covering the former surface impoundments.

Following are the descriptions of the remedial components that address the ground water contamination for Alternative 3.

16.2.3.1 Ground Water Hydraulic Control and Extraction Component

For the ground water monitoring component of Alternative 3, hydraulic control of the affected ground water plume would be maintained through the installation and operation of fourteen (14) extraction wells in Zone A and six (6) extraction wells in Zone B at a cumulative extraction flow rate of 40 gallons per minute (gpm). The extracted ground water would be collected and conveyed to a central treatment compound located in the North Area of the Site.

The extraction and treatment system potentially could be used to attempt to recover and treat NAPL in the Site groundwater. At the treatment compound, the water would be pumped to a sedimentation/surge tank and then a low profile aeration (*e.g.*, tray air stripper) treatment system for VOC removal prior to discharge to a City of Freeport sanitary sewer inlet to be located on the north side of Marlin Avenue. Based on the assumption of POTW discharge, no additional treatment would likely be needed. In the event that discharge to the POTW was not feasible and discharge to the Intracoastal Waterway was required, additional effluent treatment prior to discharge would likely be necessary.

Based on the concentrations of VOCs detected within the affected ground water plume, it is assumed that off-gas from the aeration unit would require treatment through a catalytic oxidation unit fueled by an on-site propane tank. The effectiveness of the treatment system would require monitoring through periodic effluent sampling and analysis and air emissions testing such as organic vapor meter monitoring. The alternative's effectiveness in terms of plume migration control would be verified through a monitoring and statistical evaluation program. The EPA's guidance document titled, "Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities, Unified Guidance" (March 2009, USEPA Office of Resource Conservation and Recovery, EPA 530-R-09-007) would be used in this evaluation.

17.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The NCP requires that the alternatives be evaluated against nine evaluation criteria. The following sections of the ROD summarize the relative performance of the alternatives by highlighting the key differences among the alternatives in relation to the nine criteria. These nine criteria are categorized into three groups: threshold, balancing, and modifying. The threshold criteria must be met in order for an alternative to be eligible for selection. The threshold criteria are overall protection of human health and the environment and compliance with ARARs. The balancing criteria are used to weight major tradeoffs among alternatives. The five balancing criteria are long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; short-term effectiveness; implementability; and cost. The modifying criteria are state acceptance and community acceptance.

Based on the initial screening of technologies and evaluation of alternatives, three remedial alternatives were considered in more detail in the FS (PBW 2011c). Following is a comparative analysis of the remedial alternatives that explains the rationale for the selection of Alternative 2 (Ground Water Controls and Monitoring) as the Selected Remedy for the Site.

17.1 Overall Protection of Human Health and the Environment

The overall protection of human health and the environment criterion addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or ICs. The overall assessment of protection considers each alternative's long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Overall protection of human health and the environment is considered a threshold criterion that must be met by the selected alternative.

Alternative 1 provides no additional protection of human health and the environment beyond the current restrictive covenants on Lots 55, 56, and 57 that require future building design to preclude indoor vapor intrusion. Thus Alternative 1 fails to adequately address the RAOs of verifying the stability of the affected ground water plume, and maintaining protection against potential exposures to VOCs at levels posing an unacceptable risk via the ground water to indoor air pathway for an industrial/commercial worker. It fails to ensure the continued effectiveness of the North Area cap. In contrast, Alternatives 2 (Ground Water Controls and Monitoring) and 3 (Ground Water Containment) adequately address the RAOs and provide overall protection of human health and the environment. Alternatives 2 and 3 provide this protection through an ongoing ground water monitoring program to verify that the affected ground water plumes remain stable and do not expand beyond the areas for which restrictive covenants provide protection against potential exposures via the ground water to indoor air pathway. Alternative 3 includes this ground water monitoring program, and also uses a ground water extraction and treatment program to provide hydraulic control as a measure of protection. Alternatives 2 and 3 also provide protection through the maintenance and repair of the existing surface impoundments cap which will prevent infiltration of rainwater into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. In summary, Alternatives 2 and 3 meet this threshold criterion, but Alternative 1 does not.

While Alternative 3 adds additional safeguards against migration of the contaminated ground water plume, the RI data indicates that the contaminated ground water plume currently appears stable. This data demonstrates the limited extent of contaminant migration observed during the 27 to 38 years since operation and closure of the former surface impoundments and also the low ground water velocity at the Site. The data also shows the presence of both chlorinated solvents and their degradation products indicating that the natural breakdown of at least some VOCs may be contributing to the plume's stability. Thus, the hydraulic barrier does not appear necessary at this point given that the contaminated ground water is currently not mobile. While Alternative 3 might provide treatment of NAPL in the Site ground water, as discussed in Section 18.0 (Principal Threat Wastes) of this ROD, extraction and treatment of NAPL at the Site would be ineffective because the NAPL is dispersed and would be difficult to locate.

Alternative 2 provides overall protection of human health and the environment. It addresses the RAOs of ensuring no further migration of the VOC and SVOC plumes in Zones A and B, both in terms of lateral extent and the absence of impacts above screening levels to underlying GWBUs through both ground water monitoring and repair and maintenance of the surface impoundments cap. The cap will prevent infiltration of rainwater into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. Alternative 2 also addresses the RAO of maintaining protection against potential exposures to VOCs at levels posing an unacceptable risk to commercial/industrial workers via the ground water to indoor air pathway by using the monitoring component to identify if any plume expansion is occurring. In addition, Alternative 2 addresses the RAO of preventing potential future exposure to remaining waste material in the former surface impoundments through continued repair and maintenance of the cap. The existence and maintenance of the cap will eliminate a point of exposure and also provides for protection of human health and the environment. It addresses the RAOs of preventing land use other than commercial/industrial and preventing use of ground water at the Site through restrictive covenants.

17.2 Compliance with Applicable or Relevant and Appropriate Requirements

Section 121(d) of CERCLA and the NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA §121(d)(4). Compliance with ARARs is considered a threshold criterion that must be met by the selected alternative.

Applicable requirements are those cleanup and control standards and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those State standards that are identified by a state in a timely manner and that are more stringent than Federal requirements may be applicable. Relevant and appropriate requirements are those cleanup and control standards and other substantive requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site.

The three categories of ARARs are location-, chemical-, and action-specific requirements. Chemical-specific ARARs are health- or risk-based numerical values or methodologies that specify the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment. Location-specific ARARs are restrictions placed on the types of activities that can be conducted or on the concentration of hazardous substances that can be present solely because of the location where they will be conducted. Action-specific ARARS are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the specific remedial activities selected.

Chemical-specific ARARs that could be applicable to the Site, under Alternatives 2 and 3, are Resource Conservation and Recovery Act (RCRA) waste classification requirements, specifically the RCRA hazardous waste criteria specified in 40 CFR 261 Subpart C. These ARARs apply to wastes that are generated as part of Site remedial actions. These requirements, along with Texas waste classification rules provided in 30 TAC 335 Subchapter R, would be used to determine the classification (*i.e.*, hazardous or non-hazardous Class 1, 2, or 3) for any wastes managed at an off-site treatment, storage or disposal facility. Also, the Site is adjacent to the Intracoastal Waterway, and this portion of the Intracoastal Waterway is a tidal water body. A tidal water body is by definition deemed to be a sustainable fishery (30 TAC §307.3(a)(67)). Therefore, surface water concentrations in the Intracoastal Waterway are required to meet the fish-only criteria for human health as specified in the Texas Surface Water Quality Standards (30 TAC §307.6(d)(2)(B)).

Location-specific ARARs that could be applicable to the Site, under Alternatives 2 and 3, consist of requirements applicable to wetlands, critical habitat for endangered or threatened Species, coastal zones, and floodplains. Much of the North Area is considered wetlands. A primary potential ARAR related to wetlands is Section 404(b)(1) of the Clean Water Act (CWA), promulgated as regulation in 40 CFR 230.10, which generally prohibits discharge of dredged or fill material to wetlands, subject to consideration of practicable alternatives and the use of mitigation measures. Section 404 would be considered an ARAR for the Site remedial action involving excavation of wetlands areas or placement of fill into wetlands for access road construction.

The Final SLERA (PBW 2010a) notes a number of endangered/threatened species listed as present in Brazoria County by the United States Fish and Wildlife Service. None of these species have been noted at the Site but they are known to live in or on, feed in or on, or migrate through the Texas Gulf Coast and estuarine wetlands. Remedial actions that impact rare, threatened, and endangered species may be subject to applicable Federal and State regulations that include 40 CFR §6.302(h) (EPA Procedures for Implementing Endangered Species Protection Requirements Under the Endangered Species Act), 40 CFR §230.30 (Potential Impacts on Biological Characteristics of the Aquatic Ecosystem), 50 CFR Part 402 (Interagency Cooperation – Endangered Species Act of 1973, as Amended), and 31 TAC §501.23(a) (Texas Coastal Coordination Council Policies for Development in Critical Areas). For coastal zones, the Coastal Zone Management Act of 1972 (16 USC Section 1451 et. seq.) requires the development and implementation of programs to manage the land and water resources of the coastal zone, including ecological, cultural, historic, and aesthetic values. Remedial actions that impact the coastal zone are subject to 15 CFR Part 923 (Coastal Zone Management Program Regulations). For floodplains, remedial alternatives involving on-site treatment, storage or disposal facilities for RCRA hazardous waste at the site are subject to the 40 CFR 264.18(b) requirements that they be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood.

Action-specific ARARs that could be applicable to the Site, under Alternative 3, consist of RCRA unit-specific standards, air emissions, and effluent discharge. If hydraulic control of affected ground water is provided by a ground water extraction and treatment system, the treatment system may be treating a hazardous waste (*i.e.*, the contaminated ground water may be characteristically hazardous due to concentrations of certain contaminants such as TCE). Thus, the unit-specific RCRA design and operating standards for units that treat hazardous waste must be considered. In addition, several air emission standards must be considered. Under RCRA, there are several exemptions from the unit-specific management standards for units that treat hazardous waste (40 CFR 264.1[g]), including wastewater treatment units. A wastewater treatment unit is defined in 40 CFR 260.10 as, "a device which is part of a wastewater treatment facility that is subject to regulation under either Section 402 or 307(b) of the Clean Water Act, receives and treats or stores an influent wastewater that is a hazardous waste, and meets the definition of a tank or tank system. If the ground water treatment system uses an air stripper to remove VOCs from the ground water, air emissions will be generated by the treatment system that may be subject to several Federal and State air quality regulations. These regulations include, New Source Performance Standards (40 CFR Part 60), National Emission Standards for Hazardous Air Pollutants (40 CFR Parts 61 and 63), RCRA Air Emissions Requirements (40 CFR Part 264, Control of Air Pollution from Volatile Organic Compounds (30 TAC Chapter 115); and Permits by Rule (Waste Processes and Remediation [30 TAC Chapter 106, Subchapter X]). If the effluent from a ground water extraction and treatment system is discharged to the City of Freeport POTW, the City's industrial discharge rates and ordinances would apply to this discharge. As such an industrial wastewater discharge permit is required by the City since discharge limits and monitoring/reporting would be subject to City standards described in Chapter 51 of the City of Freeport Code of Ordinances.

An action-specific ARAR under the 30 TAC §330.457 requirements for municipal solid waste landfill units may be relevant and appropriate to the existing cap, under Alternatives 2 and 3, specifically the §330.457(3)(b) requirement that Class I industrial solid waste "be covered with a four-foot layer of compacted clay-rich soil," which is identified as having a coefficient of permeability no greater than 1.0×10^{-7} cm/sec. As detailed in the RI Report, laboratory-measured hydraulic conductivities for the existing cap material ranged from 5.0×10^{-9} to 3.5×10^{-8} cm/sec. These values are approximately one-third or less of the 1.0×10^{-7} cm/sec value specified in §330.457(3)(b), thus indicating that the existing cap can be considered functionally equivalent to a four-feet thick cap constructed of clay with 1.0×10^{-7} cm/sec hydraulic conductivity. Additionally, the requirements under 40 CFR (Subpart K) §264.228 also apply to the existing cap which requires that, at closure, a surface impoundment must be covered with a final cover that has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present. The existing cap meets this ARAR because it is constructed of compacted soil (*i.e.*, clay) from the same area as the impoundments and therefore will have a permeability that is the same or less than the uncompacted natural bottom soils present. Another action-specific ARAR is the MBTA which is a requirement for the repair and maintenance activities of the cap. More specifically, grading and clearing of brush from the cap during the nesting season (usually April 1 thru July 15) would be preceded by a survey conducted by a qualified biologist. The survey would investigate the vegetation growing on the cap for nests. If active nests are identified they would be avoided until the young have fledged or the nests have been abandoned.

All three alternatives comply with the chemical-specific ARARs associated with Site-specific risk levels developed in the BHHRA. Alternatives 2 and 3 would require appropriate classifications of waste generated through the sampling of monitoring wells, and for Alternative 3, waste generated by the extraction and treatment system. Since Alternative 1 requires no other action, there are no applicable location-specific or action-specific ARARs for which compliance is needed. The location-specific ARARs associated with wetland and coastal zone habitats at the Site and ARARs related to the existing former surface impoundments cap and the MBTA are a consideration for Alternative 2, but would not be expected to pose any significant compliance concerns or implications for this alternative due to the limited nature of the action to be taken. The location-specific ARARs would be a more significant consideration for Alternative 3, which would involve much more extensive construction within these areas and thus have a potential for their disruption and/or need for mitigation or restoration. Multiple action-specific ARARs could potentially apply to Alternative 3, including ARARs relating to unit-specific standards under RCRA, air emissions, and effluent discharge. The existing former surface impoundments cap complies with an action-specific ARAR related to its composition for Alternatives 2 and 3. The ground water treatment and discharge components of Alternative 3 would need to be designed to comply with these action-specific ARARS. Thus all three alternatives meet this threshold criterion, but Alternative 3 has a higher potential to present potential compliance concerns or implications than Alternatives 1 and 2.

The annual ground water sampling to be performed as part of Alternative 2 would have minimal effects on the wetland and coastal zone habitats in which the monitoring wells are constructed, and thus the alternative complies with the location-specific ARARs associated with those areas. Action-specific ARARs that apply to Alternative 2 are related to the existing cap at the former surface impoundments, which complies with its respective ARARs and the MBTA.

17.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup levels and RAOs have been met. This criterion includes the consideration of residual risk that will remain on-site following remediation and the adequacy and reliability of controls. Long-term effectiveness and permanence is considered a balancing criterion. The following factors are considered in the evaluation of this criterion:

- Adequacy of remedial controls,
- Reliability of remedial controls, and
- Magnitude of the residual risk.

Alternative 1 provides the lowest long-term effectiveness and permanence because it is not effective in the long-term in meeting the RAOs or maintaining protection of human health and the environment. Alternatives 2 and 3 are effective in meeting the RAOs over the long-term and provide a generally similar level of long-term effectiveness and permanence. Both would be expected to be reliable. While Alternative 3 adds hydraulic control through extraction and treatment of ground water, this provides little additional long-term effectiveness because currently the contaminated ground water plume is stable, and the monitoring component will verify that this continues to be true. Alternative 3 also would not provide significant additional long-term effectiveness because it would not be effective in treating the NAPL in the ground water due to the difficulty of locating any NAPL pools that may be present in the underlying water-bearing units. While soil boring and ground water samples indicate the likely presence of NAPL in Site ground water, none was actually observed in the ground water at any of the existing monitoring wells. Additionally, the heterogeneity of the soil/ground water matrices and the extremely low hydraulic conductivities of the underlying GWBUs (see Section 12.5.2 [Site Hydrogeology]) would prohibit the successful remediation of the ground water and would not be cost effective. The water-bearing units are fine-grained heterogeneous mixtures of sands, silts, and clays. The heterogeneous nature of these zones would result in highly variable amounts and locations of residual and free-phase NAPL which would be difficult to recover and would remain as a continuing and long-term source (*e.g.*, decades or centuries) of contamination for the ground water. The physical and chemical properties of the NAPL, including their relatively low solubility, high specific gravity, and the tendency to diffuse into fine-grained material, such as the material present in the underlying soil matrices, can also impact the effectiveness of conventional remedial technologies, such as ground water extraction described under Alternative 3.

The existing surface impoundments cap, under Alternatives 2 and 3, will maintain reliable protection of human health and the environment over time. The cap will prevent rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments, and also prevent the potential for exposure to the remaining waste materials under the cap.

Alternatives 2 and 3 both include long-term monitoring and management components, although those long-term components are much more complex for Alternative 3. Alternative 2 would not be expected to pose any appreciable potential habitat impacts, while habitat impacts from Alternative 3 would be expected to be more significant. Taken as a whole, this analysis suggests that Alternative 2 provides the highest long-term effectiveness and permanence, Alternative 3 provides a slightly lower long-term effectiveness and permanence, and Alternative 1 does not provide long-term effectiveness and permanence.

Alternative 2 is effective at protecting human health and the environment over the long-term. It contains a long-term ground water monitoring component which will include maintenance of the monitoring well network. Institutional controls and cap maintenance also will prevent exposure to risks at unacceptable levels. The resultant risks, if any, that might occur should the monitoring program fail to detect any plume expansion would be expected to be minor, given the limited extent of contaminant migration observed during the 27 to 38 years since operation and closure of the former surface impoundments and the low ground water velocity at the Site. Thus, Alternative 2 would be expected to be reliable in meeting the RAOs over the long-term. Potential habitat impacts from the annual ground water monitoring events would be expected to be minimal. The existing surface impoundments cap, under Alternative 2, will maintain reliable protection of human health and the environment over time.

17.4 Reduction in Toxicity, Mobility, or Volume through Treatment

The reduction of toxicity, mobility, or volume through treatment criterion refers to the anticipated performance of the treatment technologies that may be included as part of a remedy. It also refers to the evaluation of an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contamination present. Reduction of toxicity, mobility, or volume through treatment is considered a balancing criterion. Although CERCLA includes a statutory preference for treatment, this criterion is not a threshold that must be met. The preference is satisfied when treatment reduces the principal threats through the following mechanisms:

- Destruction of toxic contaminants,
- Reduction in contaminant mobility (*i.e.*, migration of soil particles, since the ground water fate and transport model for the Site does not indicate significant migration of ground water contaminants),
- Reduction in the total mass of toxic contaminants, and
- Reduction in the total volume of contaminated media.

Under all three alternatives, there would be no significant reductions in toxicity, mobility, and volume of contaminants at the Site through treatment. Treatment of the extracted ground water and off-gas from the treatment system as part of Alternative 3 would reduce the toxicity of the extracted ground water and the mobility and volume of contamination in the affected ground water plume, but the success of the extraction and containment technology is doubtful given the difficulties associated with the remediation of a ground water plume containing residual and possibly free-phase NAPL. While not treatment, the existing surface impoundments cap, to be maintained under Alternatives 2 and 3, will reduce the mobility of the contaminants in the ground water by preventing rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments.

17.5 Short-Term Effectiveness

The short-term effectiveness criterion addresses the effects of the alternative during the construction and implementation phase until the RAOs are met. Under this criterion, alternatives are evaluated for their effects on human health and the environment during implementation of the remedial action. Short-term effectiveness is considered a balancing criterion. The following factors are considered when evaluating the short-term effectiveness of a remedial alternative:

- Exposure of the community during implementation of the remedy,
- Exposure of workers during construction,
- Environmental impacts, and
- Time to achieve RAOs.

Alternative 1 provides the lowest short-term effectiveness because it is not effective in the short-term in meeting RAOs or maintaining protection of human health and the environment. Alternatives 2 and 3 are both effective at meeting the RAOs and providing protection of human health and the environment in the short-term. Alternative 2 does not present any associated risks to the community or on-site workers or any appreciable environmental impacts as part of its implementation. Alternative 3 would present safety risks to on-site workers similar to those inherent in any construction project, and would present slight safety risks to the local community due to the temporary increase in traffic to the Site during the construction period. Alternative 3 would probably result in some local habitat impacts in the extraction well and treatment areas during the construction period. The existing surface impoundments cap, under Alternatives 2 and 3, is effective in the short-term since it does not have to be constructed and only needs repair and maintenance. Alternative 2 provides the highest short-term effectiveness, Alternative 3 provides a slightly lower short-term effectiveness, and Alternative 1 is not considered effective in the short-term.

Alternative 2 is effective at meeting the RAOs and providing protection of human health and the environment in the short-term. Since the primary field activities consists of monitoring and maintaining existing monitoring wells and maintaining the existing former surface impoundments cap, it does not present any appreciable associated risks to the community or on-site workers nor does it result in any environmental impacts as part of its implementation.

17.6 Implementability

The implementability criterion addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered. Implementability is considered a balancing criterion. The following factors are considered when evaluating the implementability of a remedial alternative:

- Ability to construct the technology,
- Monitoring requirements,
- Availability of equipment and specialists, and
- Ability to obtain approvals from regulatory agencies.

Alternative 1 is the most easily implemented since it requires no action. Alternatives 2 and 3 are both readily implemented as both utilize widely accepted and proven technologies. Alternative 2 is considered more implementable than Alternative 3 because Alternative 3 involves the technologically more complex components of treatment system construction and operation, including catalytic oxidation of air stripper off gas treatment, and the administratively more complex component of effluent discharge to a POTW or through a TPDES permit.

Alternative 2 is easily implemented since the alternative provides for monitoring of existing monitoring wells and does not require the installation of any new wells. The former surface impoundments cap already exists and can be readily maintained through the O&M program. Ground water monitoring programs and institutional controls are commonly used and accepted remedial components that are easily implemented and do not pose any significant technical or administrative feasibility concerns.

17.7 Cost

Costs to implement a remedial alternative include estimated capital and O&M costs as well as present worth costs. Capital costs consist of direct and indirect costs. Direct costs include the purchase of equipment, labor, and materials necessary to implement the alternative. Indirect costs include engineering, financial, and other services such as testing and monitoring. Annual O&M costs for each alternative include operating labor, maintenance materials and labor, auxiliary materials, and energy. Present worth cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent. Cost is considered a balancing criterion.

Since Alternative 1 involves no new actions, its cost is projected at $0 for the purposes of this evaluation. The projected present worth cost of Alternative 2 is $230,000. The projected present worth cost of Alternative 3 is $4,700,000. Tables 2 (Alternative 2 Preliminary Cost Projection) and 56 (Alternative 3 Preliminary Cost Projection) provide a detailed description of the costs to implement Alternatives 2 and 3, respectively.

17.8 State Acceptance

The state acceptance criterion considers whether the State of Texas agrees with the EPA's analysis and recommendations of the RI (PBW 2011b) and FS (PBW 2011c) Reports and the Proposed Plan (EPA 2011). State acceptance is considered a modifying criterion. The State of Texas, through the TCEQ, agrees with the EPA's decision to implement Alternative 2 (Ground Water Controls and Monitoring). The TCEQ provided technical support to the EPA during the performance of the RI/FS and commented on the Proposed Plan (EPA 2011) and this ROD.

17.9 Community Acceptance

The community acceptance criterion considers whether the local community agrees with the EPA's analyses of the technical documentation developed during the investigation of the Site and identification of the preferred alternative in the Proposed Plan (EPA 2011). Comments received from the public on the Proposed Plan are an important indicator of community acceptance. Community acceptance is considered a modifying criterion.

The EPA conducted a public meeting on August 4, 2011, at the Velasco Community House located at 110 Skinner Street in Freeport, Texas. The EPA held this public meeting to explain the Proposed Plan (EPA 2011) and the EPA's preliminary recommendation of implementation of Alternative 2 (Ground Water Controls and Monitoring) for the Site. Oral and written comments were accepted at the meeting. The public comment period began on July 9, 2011, and ended on August 22, 2011. The EPA encouraged the public to participate in the public meeting and to review and comment on the EPA's preliminary recommendation of implementing Alternative 2 (Ground Water Controls and Monitoring) presented in the Proposed Plan. Several comments received during the public meeting and the public comment period acknowledged a preference for the implementation of Alternative 3 (Ground Water Containment) of the Proposed Plan. The EPA responded to these comments in the Responsiveness Summary (Appendix A – Responsiveness Summary) of this ROD by providing an additional description of the rationale for the Selected Remedy.

17.10 Summary of Comparative Analysis of Alternatives

A total of three remedial alternatives were fully evaluated during the FS (PBW 2011c) for the Site. Alternative 1 (No Action) was evaluated, as required by the NCP, and was eliminated from further consideration as a viable remedial alternative. The EPA has determined that Alternative 2 (Ground Water Controls and Monitoring), the Selected Remedy presented in this ROD, meets all of the statutory criteria for a remedy, except the statutory preference for treatment, and meets the two threshold criteria (*i.e.*, overall protection of human health and the environment and compliance with ARARs) of the NCP. The EPA has also determined that Alternative 2 provides the best balance of tradeoffs with respect to the five balancing criteria (*i.e.*, long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; short-term effectiveness; implementability; and cost) and the two modifying criteria (*i.e.*, State and community acceptance) of the NCP. The State of Texas concurs with the EPA's decision to implement Alternative 2.

18.0 PRINCIPAL THREAT WASTES

The NCP establishes an expectation that the EPA will use treatment to address the principal threat wastes at a site wherever practicable. The "principal threat" concept is applied to the characterization of "source materials" at a Superfund site. A source material is material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to soils, ground water, surface water, or air, or acts as a source for direct exposure. Principal threat wastes are those materials considered to be highly toxic or highly mobile that generally cannot be reliably contained, or would present a significant risk to human health or the environment should exposure occur. Low level threat wastes are those source materials that generally can be reliably contained and that would present only a low risk in the event of exposure (EPA 1991).

Alternative 2 (Ground Water Controls and Monitoring), the Selected Remedy described in this ROD, does not satisfy the statutory preference for treatment as a principal element. NAPL present in the ground water at the Site is considered a source material constituting principal threat waste that requires treatment; however, the EPA believes that treatment of the NAPL under Alternative 3 (Ground Water Containment), would not be effective for the following reasons and for the reasons included in the nine criteria analysis described in Section 17.0 (Comparative Analysis of Alternatives) of this ROD.

The former surface impoundments located at the North Area, which contained contaminated sludges (*i.e.*, source materials considered principal threat wastes) from the barge cleaning operations, were certified closed by the Texas Water Commission, a predecessor of the TCEQ, on August 24, 1982. The closure activities included the removal of liquids and most of the sludges, solidification of approximately 100 cubic yards of residual sludge that was difficult to excavate, and capping with three feet of clay and a hard-wearing surface (*i.e.*, shell). The former surface impoundments are believed to be the historical source of NAPL in the ground water at the Site, and the EPA believes that this source of NAPL (*i.e.*, sludges considered a principal threat waste) has been adequately addressed through the State's closure activities.

Residual NAPL was observed during the RI within the soil matrix at the base of ground water Zones A and B in the soil cores of three ground water monitoring wells. The presence of free-phase NAPL is also indicated because the ground water concentrations for several compounds in a few ground water monitoring wells exceeded 1% of the compound's solubility limit, which is often used as an indicator for the possible presence of NAPL. However, free-phase NAPL, and NAPL sheen, have not been observed in ground water samples of these or any other Site ground water monitoring wells indicating that the NAPL is not mobile, limited in extent, dispersed, and difficult to locate.

Any pools of NAPL at the Site could not be located during the RI and are likely dispersed in small localized areas in the underlying water-bearing units. It would be difficult and ineffective to treat the NAPL in the ground water due to the difficulty of locating these pools. Additionally, the heterogeneity of the soil/ground water matrices and the extremely low hydraulic conductivities of the underlying GWBUs (see Section 12.5.2 [Site Hydrogeology]) are important factors affecting NAPL fate and transport which would prohibit the successful treatment of the NAPL and would not be cost effective. The water-bearing units are fine-grained heterogeneous mixtures of sands, silts, and clays. The heterogeneous nature of these zones would result in highly variable amounts and locations of residual and free-phase NAPL which would be difficult to recover, and which would remain as a continuing and long-term source (*e.g.*, decades or centuries) of contamination for the ground water. The physical and chemical properties of the NAPL, including the relatively low solubility, high specific gravity, and the tendency to diffuse into fine-grained material, such as the material present in the underlying soil matrices, can also impact the effectiveness of conventional remedial technologies, such as ground water extraction described under Alternative 3 (Ground Water Containment).

19.0 SELECTED REMEDY

The rationale for the EPA's selection of Alternative 2 (Ground Water Controls and Monitoring) as the Selected Remedy for the Site is dependant on the nine evaluation criteria required by the NCP. The Selected Remedy addresses the RAOs identified for the Site, and fulfills the two threshold criteria (*i.e.*, protection of human health and the environment and compliance with ARARs) that must be met. Consideration of the five balancing criteria (*i.e.*, long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost) and the two modifying criteria (*i.e.*, State and community acceptance) also influenced the EPA's decision to implement Alternative 2. The State of Texas concurs with the EPA's Selected Remedy for the Site.

The EPA selected Alternative 2 (Ground Water Controls and Monitoring) as the preferred alternative to address the RAOs for the Site based on the comparative analysis of alternatives described in this ROD. Alternative 1 fails to meet the threshold criterion of overall protection of human health and the environment and thus is eliminated from further consideration. Alternatives 2 and 3 are considered roughly equivalent with regard to the threshold criteria of overall protection of human health and the environment and compliance with ARARs, and the balancing criterion of long-term effectiveness and permanence. Alternative 3 is slightly superior with regard to the balancing criterion of reduction of toxicity, mobility, and volume through treatment, although Alternative 3 is unlikely to be effective in providing significant treatment of NAPL for the reasons discussed in Section 18.0 (Principal Threat Wastes) of this ROD. Alternative 2 is considered superior to Alternative 3 with regard to the balancing criteria of short-term effectiveness, implementability, and cost. The following sections of this ROD describe the EPA's Selected Remedy for the Site.

19.1 Summary of the Rationale for the Selected Remedy

The Selected Remedy described in this ROD is necessary to protect the public health or welfare or the environment from actual releases of hazardous substances into the environment. The human health and ecological risk assessments concluded that current or potential future Site conditions pose unacceptable risks to human health or to the environment due to the potential for human exposure to VOCs in any future buildings, at the North Area, at levels posing an unacceptable risk for commercial/industrial workers via the ground water to indoor air pathway. The Selected Remedy will address the Remedial Action Objectives, identified in Section 15.0 (Remedial Action Objectives) of this ROD, and is cost-effective because the remedy's costs are proportional to its overall effectiveness. The EPA is also selecting this remedy because the previous closure activities performed by the State, at the former surface impoundments located at the North Area (see Section 9.1.1 [Closure of the Former Surface Impoundments]), and the EPA's Removal Action, at the South Area (see Section 9.2 [CERCLA Removal Action]), reduced the existing and potential risks to human health and the environment.

The existing surface impoundments cap is an essential component of the Selected Remedy since it will prevent rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. If the contaminated ground water plume were to discharge into the waterway, it could pose a risk to contact recreational receptors. The former surface impoundments cap also addresses the RAO of preventing exposure to residual materials underlying the cap.

Alternative 2 is cost-effective because the remedy's costs are proportional to its overall effectiveness. The present worth costs (assuming a 30 year period and 7% discount factor), including contingencies, is $230,000. Table 2 (Alternative 2 Preliminary Cost Projection) provides a detailed description of the costs to implement Alternative 2. The projected present worth cost of Alternative 3 is more than 20 times greater than the projected present worth cost of Alternative 2. Additionally, the success of the extraction and containment technology under

Alternative 3 is doubtful given the difficulties associated with the treatment of residual and possibly free-phase NAPL which are discussed in Sections 18.0 (Principal Threat Wastes) and 20.5 (Preference for Treatment as a Principle Element) of this ROD.

19.2 Description of the Selected Remedy

Following is a description of each component of the Selected Remedy. Although the EPA does not expect significant changes to this remedy, it may change “somewhat” as a result of the remedial design and construction processes. Any changes to the remedy described in this ROD would be documented using a technical memorandum in the Administrative Record, an Explanation of Significant Differences, or a ROD Amendment, as appropriate and consistent with the applicable regulations.

The Selected Remedy, Alternative 2 (Ground Water Controls and Monitoring), includes the following components:

1. Review and evaluation of the current restrictive covenants prohibiting ground water use at the Site and requiring commercial/industrial land use and protection against indoor vapor intrusion for building construction on Lots 55, 56, and 57;

2. Modification of the existing Institutional Controls (ICs) to address any issues identified with the current restrictive covenants after review, identify the type and location of hazardous substances, identify the location of the existing cap and restrict actions that might affect the integrity of the cap, and any other necessary modifications;

3. A cap over the former surface impoundments;

4. Annual ground water monitoring, and monitoring as a part of the Five-Year Reviews, to confirm stability of the affected ground water plume; and

5. Implementation of an Operation and Maintenance Plan to provide ground water monitoring and inspection/repair of the cap covering the former surface impoundments.

Following are the descriptions of the remedial components that address the ground water contamination for Alternative 2.

19.2.1 Institutional Controls Component

ICs, in the form of restrictive covenants, would continue to be implemented to achieve the RAOs of preventing human exposure to VOCs in any future buildings at levels posing an unacceptable risk for commercial/industrial workers via the ground water to indoor air pathway (*i.e.*, indoor vapor intrusion) to prevent land use other than commercial or industrial, and to prevent ground water use. ICs for the ground water would be implemented to ensure that the ground water underlying the Site is not used for any purpose, because, although the ground water is not potable, industrial use could occur in the future.

The current restrictive covenants will be reviewed and evaluated to insure their protectiveness. In conjunction with the restrictive covenant review/evaluation component, it is anticipated that one or more modifications to the current ICs may be required. These modifications may include the addition of supplemental information regarding the type and location of hazardous substances at the Site, including the contamination in the ground water plume, such as a metes and bounds description of the affected area and a list of the contaminants present, clarification of all use restrictions in accordance with the remedial action, and other changes as appropriate to reflect the requirements of Title 30 of the Texas Administrative Code, Section 350.111, and any applicable state and federal rules and statutes. The existing ICs also will be modified and/or supplemented to identify the location of the existing Site cap and restrict actions that might affect the integrity of the cap.

19.2.2 Surface Impoundments Cap Component

The RAOs of preventing further migration of the VOC and SVOC plumes in Zones A and B, both in terms of lateral extent and the absence of impacts above screening levels to underlying GWBUs, and preventing potential future exposure to remaining waste material in the former surface impoundments will be met by the existing surface impoundments cap. The cap will be maintained and repaired to insure its continued effectiveness in preventing water infiltration and exposure to materials underlying the cap.

19.2.3 Ground Water Monitoring Component

The RAO of preventing further migration of the VOC and SVOC plumes in Zones A and B, both in terms of lateral extent and the absence of impacts above screening levels to underlying GWBUs, will be achieved under the ground water monitoring component of Alterative 2. The monitoring component will also address the RAO of preventing human exposure to VOCs in any future buildings at levels posing an unacceptable risk for commercial/industrial workers via the ground water to indoor air pathway. The stability of the affected ground water plume will be verified by an evaluation of the temporal trends of the primary ground water COIs above their respective extent evaluation criteria in perimeter monitoring wells using a Mann-Kendall test or similar statistical trend analysis. The EPA's guidance document titled, "Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities, Unified Guidance" (March 2009, USEPA Office of Resource Conservation and Recovery, EPA 530-R-09-007) will be used in this evaluation. The ground water COIs include 1,1,1-TCA; 1,1-DCE; 1,2,3-TCP; 1,2-DCA;

benzene; cis-1,2-DCE; methylene chloride; PCE; TCE; and VC. For the purposes of this evaluation, Zones A and B perimeter monitoring wells will be selected as part of the Operation and Maintenance Plan. Should such trend analysis indicate a statistically significant increase (SSI), additional sampling will be performed at the indicated location within 30 days of determination of the SSI to confirm the trend. Should a confirmed SSI be indicated, then an evaluation of possible plume expansion will be performed by the installation of one or more additional monitoring wells outward from the affected well (or wells), as necessary, to define the plume boundaries.

19.2.4 Operations and Maintenance Component

The O&M component of Alternative 2 will provide for ground water monitoring and inspection and maintenance/repair of the cap covering the former surface impoundments.

19.2.5 Five-Year Review Component

Because Alternative 2 will result in hazardous substances remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory five-year review would be conducted no less often than every five years after initiation of the remedial action to ensure that the remedy is, or would continue to be, protective of human health and the environment.

19.3 Cost Estimate for the Selected Remedy

Table 2 (Alternative 2 Preliminary Cost Projection) details the estimated costs to implement Alternative 2. The estimated present worth cost to implement the Selected Remedy presented in this ROD is $230,000. The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the Operation and Maintenance of the remedial alternative. Major changes would be documented in the form of a technical memorandum in the Administrative Record file, an Explanation of Significant Differences, or a ROD amendment, as appropriate and consistent with the applicable regulations. This cost estimate is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

19.4 Expected Outcomes of the Selected Remedy

Following are the expected outcomes of the Selected Remedy in terms of the risk reduction achieved as a result of the response action, resulting land and ground water uses, and the anticipated community revitalization impacts.

19.4.1 Reduction of Risk

The EPA's Selected Remedy will reduce or eliminate the cancer risks and noncancer health effects associated with the possible future exposure to an indoor industrial worker from Site contaminants if a building is constructed over impacted ground water in the North Area. Potential cancer risks in the North Area, using maximum shallow Zone A ground water concentrations and the J&E VIM model, were predicted to be greater than 1.0×10^{-4}, while the HIs were estimated to be greater than 1. Generally, the EPA considers a remedial action to be warranted at a site where the ELCR exceeds 1.0×10^{-4}. An HQ or HI greater than 1 indicates some potential for adverse non-cancer health effects associated with the COCs for the Site.

Potential cancer risks in the North Area were predicted to be 2.0×10^{-2}, which is 200 times greater than the EPA's risk level of 1.0×10^{-4}. This means that for every 10,000 people that could be exposed 200 extra cancer cases may occur as a result of exposure to Site-related contaminants (*i.e.* VOCs) via the ground water to indoor air pathway. The HI was estimated to be 18.0 indicating that non-cancer health effects are possible via this pathway. Estimated risks from Zone A ground water at the South Area were below the EPA's goals; therefore, adverse risks associated with the vapor intrusion pathway are unlikely in this area at this time.

The existing surface impoundments cap will prevent rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. The existence and maintenance of the surface impoundments cap will also eliminate a point of exposure to residual waste materials underlying the cap and will also eliminate many of the routes of exposure; specifically, incidental ingestion and dermal contact for recreational swimmers as well as ingestion of seafood by subsistence and recreational fishermen. If the cap were removed or not maintained, then these routes of exposure would exist leading to increased carcinogenic risks and non-carcinogenic health effects.

19.4.2 Available Land Uses

The South Area of the Site can immediately be used for industrial/commercial purposes since the restrictive covenants preventing land use other than for industrial/commercial use are currently in effect. The Site is not expected to be utilized for residential purposes in the near future due to the current zoning of the Site as "industrial." Additionally, most of the North Area, which is covered by the restrictive covenants, consists entirely of wetlands, except for approximately 2.2 acres which could sustain a building, and also includes the cap on the former surface impoundments.

19.4.3 Available Ground Water Uses

Due to its high natural salinity, ground water at the Site in zones A, B, and C is classified as non-potable. Because of the contamination in the Site ground water, restrictive covenants will also prevent its use for industrial or other purposes.

19.4.4 Anticipated Community Revitalization Impacts

The Selected Remedy will provide revitalization impacts to the local community because it will allow the Site to be immediately developed for reuse (*i.e.*, commercial and/or industrial land use). The ground water monitoring, cap, and O&M components of the Selected Remedy will not hinder the overall development of the Site for reuse.

20.0 STATUTORY DETERMINATIONS

The EPA has determined that the Selected Remedy for the Site meets each of the statutory mandates of Section 121 of CERCLA, except the statutory preference for treatment as a principle element, and, to the extent practicable, the requirements of the NCP. Pursuant to CERCLA, the EPA must select remedies that are protective of human health and the environment, comply with Federal and State requirements that are applicable or relevant and appropriate to the remedial action (unless a statutory waiver is justified), are cost-effective, and utilize permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as a principal element and a bias against off-site disposal of untreated wastes. Also, the NCP §300.430(f)(4)(ii) requires a statutory five-year review when hazardous substances, pollutants, or contaminants remain at a site above levels that allow for unlimited use and unrestricted exposure to ensure that the remedy is, or will continue to be, protective of human health and the environment. The following sections of the ROD discuss how the Selected Remedy meets, or does not meet, each of these requirements.

20.1 Protection of Human Health and the Environment

Alternative 2 provides overall protection of human health and the environment. It addresses risks posed by the VOC and SVOC contamination in the Site ground water, and the risks posed by indoor vapor intrusion from the VOCs in the ground water, by monitoring the contaminated ground water plume to insure its continued stability within its current boundaries and to identify if any plume expansion is occurring. It also addresses the risks identified with further migration of the VOC and SVOC plumes in Zones A and B, both in terms of lateral extent and the absence of impacts above screening levels to underlying GWBUs, and preventing potential exposure to wastes remaining in the former surface impoundments through maintenance of the surface impoundments cap. The cap will prevent rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments. The existence and maintenance of the surface impoundments cap will also eliminate a point of exposure to the residual waste materials under the cap and routes of exposure including incidental ingestion and dermal contact for recreational swimmers as well as ingestion of seafood by subsistence and recreational fishermen. It insures that future use of the Site is protective by using institutional controls preventing land use other than commercial/industrial and preventing use of ground water at the Site through restrictive covenants, and by requiring protection against indoor vapor intrusion. Institutional controls will also help maintain the integrity of the Site cap.

Alternative 2 is effective at meeting the RAOs and providing protection of human health and the environment in the short-term. Since the primary field activities consists of monitoring and maintaining existing monitoring wells and maintaining the existing former surface impoundments cap, it does not present any appreciable associated risks to the community or on-site workers nor does it result in any environmental impacts as part of its implementation.

Alternative 2 is effective at protecting human health and the environment over the long-term. It contains a long-term ground water monitoring component which will include maintenance of the monitoring well network. The monitoring component will detect any plume expansion so that it may be addressed, if appropriate. Potential habitat impacts from the annual ground water monitoring events would be expected to be minimal. The existing surface impoundments cap will maintain reliable protection of human health and the environment over time since it will prevent rainwater from infiltrating into the materials underlying the cap that could cause leaching of contaminants into the ground water and possibly accelerate the rate of plume migration towards the Intracoastal Waterway's surface water and sediments, as well as preventing exposure to residual waste materials underlying the cap.

20.2 Compliance with Applicable or Relevant and Appropriate Requirements

The Selected Remedy for the Site will comply with all Federal and any more stringent State ARARs that are applicable to the remedial action for the Site. Sections 121(d) of CERCLA and the NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations which are collectively referred to as ARARs, unless such ARARs are waived under CERCLA §121(d)(4).

The annual ground water sampling to be performed as part of this alternative would have minimal effects on the wetland and coastal zone habitats in which the monitoring wells are constructed, and thus the alternative complies with the location-specific ARARs associated with those areas. Implementation of this alternative will also consider critical habitat for endangered or threatened, although the potential impact on any endangered or threatened species at the Site would also likely be minimal species because the currently planned monitoring if only of existing monitoring wells and the remedy includes the existing former surface impoundments cap. Any ground water samples to be disposed will comply with RCRA regulations regarding the classification of hazardous wastes. The action-specific ARARs that apply to Alternative 2 are related to the existing cap at the former surface impoundments, which complies with its respective ARARs and will comply with the MBTA. The ARARs applicable to the Site and the Selected Remedy presented in this ROD are listed in Table 1 (List of ARARs for the Gulfco Marine Maintenance Superfund Site) and are described further in Section 17.2 (Compliance with Applicable or Relevant and Appropriate Requirements) of this ROD.

20.3 Cost-Effectiveness

The Selected Remedy is cost-effective because the remedy's costs are proportional to its overall effectiveness (40 CFR §300.430[f][l][ii][D]). This determination was made by evaluating the overall effectiveness of those alternatives that satisfied the threshold criteria (*i.e.*, protection of human health and the environment, and compliance with all ARARs). Overall effectiveness was evaluated by assessing the five balancing criteria in combination (*i.e.*, long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost). The overall effectiveness of each alternative was then compared to each alternative's costs to determine cost-effectiveness. The relationship of the overall effectiveness of this remedial alternative was determined to be proportional to its costs and hence represents a reasonable value for the money to be spent.

Alternative 2 is cost-effective because the remedy's costs are proportional to its overall effectiveness. Costs for this alternative include review and modification of institutional controls, preparation of the monitoring and cap O&M plan, and plugging and abandonment of existing monitoring wells not included in the long-term ground water monitoring program. Annual O&M costs primarily consist of sample collection and analysis, monitoring data evaluation, and well repair and maintenance, as needed. No costs are included for the existing cap, other than maintenance and repair, since it is already in place. The present worth costs (assuming a 30 year period and 7% discount factor), including contingencies, is $230,000. The projected present worth cost of Alternative 3 is more than 20 times greater than the projected present worth cost of Alternative 2, the Selected Remedy, and Alternative 3 does not provide significant additional protectiveness, as described further in Sections 17.1 (Overall Protection of Human Health and the Environment), 17.3 (Long-Term Effectiveness and Permanence), and 18.0 (Principal Threat Wastes) of this ROD. Table 2 (Alternative 2 Preliminary Cost Projection) provides a detailed description of the costs to implement Alternative 2.

20.4 Utilization of Permanent Solutions to the Maximum Extent Practicable

The EPA has determined that the Selected Remedy represents the maximum extent to which permanent solutions can be utilized in a practicable manner at the Site. Of the two alternatives that are protective of human health and the environment and comply with ARARs, the EPA has determined that the Selected Remedy provides the best balance of trade-offs in terms of the five balancing criteria (*i.e.*, long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; short-term effectiveness; implementability; and cost) and the two modifying criteria (*i.e.*, State and community acceptance). These criteria are discussed in Sections 17.3 (Long-Term Effectiveness and Permanence), 17.4 (Reduction of Toxicity, Mobility or Volume through Treatment), 17.5 (Short-Term Effectiveness), 17.6 (Implementability), 17.7 (Cost), 17.8 (State Acceptance), and 17.9 (Community Acceptance) of this ROD.

20.5 Preference for Treatment as a Principal Element

CERCLA and the NCP establish an expectation that the EPA will use treatment to address the principal threat wastes at a site wherever practicable. As discussed in more detail in Section 18.0 (Principal Threat Wastes) of this ROD, while the Selected Remedy does not satisfy the preference for treatment as a principal element, Alternative 3 would not provide significant treatment of principal threat wastes at the Site because it would be ineffective in treating NAPL in Site ground water. The EPA believes that Alternative 2 (Ground Water Controls and Monitoring) is the preferred alternative to address the RAOs for the Site based on the comparative analysis of alternatives described in this ROD.

20.6 Five-Year Review Requirements

Section 121(c) of CERCLA and the NCP §300.430(f)(5)(iii)(C) provide the statutory and legal bases for conducting five-year reviews. Because the Selected Remedy will result in hazardous substances remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted no less often than every five years after initiation of the remedial action to ensure that the remedy is, or will continue to be, protective of human health and the environment.

The public will be informed of the performance of each five-year review through a public notice in a local newspaper. The five-year reviews for this Site are:

- A regular EPA checkup on the Superfund Site that has been cleaned up, with waste left behind, to make sure the Site is still safe,
- A way to make sure the cleanup continues to protect people and the environment, and
- A chance for the public to tell the EPA about Site conditions and any concerns they may have about the Site.

21.0 DOCUMENTATION OF SIGNIFICANT CHANGES FROM PREFERRED ALTERNATIVE OF PROPOSED PLAN

The EPA has determined that significant changes to the Selected Remedy, as originally identified in the Proposed Plan (EPA 2011), were unnecessary. The Proposed Plan for the Site was released for public comment in July 2011. The Proposed Plan identified Alternative 2 (Ground Water Controls and Monitoring) as the EPA's preferred alternative. This alternative consisted of:

1) Review and evaluation of current restrictive covenants prohibiting ground water use at the Site and requiring commercial/industrial land use and protection against indoor vapor intrusion for building construction on Lots 55, 56, and 57;

2) Modification of the existing ICs to identify the type and location of hazardous substances, and other modifications;

3) A cap over the former surface impoundments;

4) Annual ground water monitoring, and as a part of the Five-Year Reviews, to confirm stability of the affected ground water plume;

5) Implementation of an Operation and Maintenance Plan to provide ground water monitoring and inspection/repair of the cap covering the former surface impoundments.

While not significant, the EPA did add additional institutional control requirements in this ROD to identify the location of the cap over the former surface impoundments and to restrict activities that might affect its continued effectiveness. In addition, while not a change to the Selected Remedy, the EPA did evaluate in this ROD the potential effectiveness of Alternative 3 to address any NAPL in Site ground water.

A public meeting was held on August 4, 2011, at the Velasco Community House located at 110 Skinner Street in Freeport, Texas. The EPA held this public meeting to explain the Proposed Plan (EPA 2011) and the EPA's preliminary recommendation of implementation of Alternative 2 (Ground Water Controls and Monitoring) for the Site. Oral and written comments were accepted at the meeting. The public comment period began on July 9, 2011, and ended on August 22, 2011. Several comments received during the public meeting and the public comment period acknowledged a preference for the implementation of Alternative 3 (Ground Water Containment) of the Proposed Plan (EPA 2011). The EPA responded to these comments, in the Responsiveness Summary (Appendix A –Responsiveness Summary) of this ROD, by providing the rationale for the Selected Remedy.

22.0 STATE ROLE

The TCEQ, on behalf of the State of Texas, has reviewed the various alternatives and has indicated its support for Alternative 2 (Ground Water Controls and Monitoring) as the Selected Remedy for this Site. The State has also reviewed the RI (PBW 2011b), BHHRA (BPW 2010b), and SLERA (PBW 2010a) Reports, to determine if the Selected Remedy is in compliance with State ARARs and environmental and facility siting laws and regulations. The State of Texas concurs with the EPA's selection of Alternative 2 as the Selected Remedy for the Site.

PART 3: RESPONSIVENESS SUMMARY

23.0 RESPONSIVENESS SUMMARY

The Responsiveness Summary (Appendix A) summarizes information about the views of the public and the support agency regarding the remedial alternatives and general concerns about the Site submitted during the public comment period. This summary also documents, in the record, how public comments were integrated into the decision-making process.

The Administrative Record file for the Site, located at the local Freeport Branch Library, TCEQ's Records Management Center, and the EPA's Region 6 office, contains all of the information and documents supporting the EPA's decision and this ROD. This Administrative Record file includes a transcript of the public meeting held by the EPA on August 4, 2011, at the Velasco Community House located at 110 Skinner Street in Freeport, Texas, to describe the preferred alternative to the public.

Several comments received during the public meeting and the public comment period acknowledged a preference for the implementation of Alternative 3 (Ground Water Containment) of the Proposed Plan (EPA 2011). The EPA responded to these comments, in the Responsiveness Summary (Appendix A –Responsiveness Summary) of this ROD, by providing the rationale for the Selected Remedy. The Responsiveness Summary summarizes the comments received during the public meeting and comment period and the EPA's responses to these comments.

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FIGURES

TABLES

APPENDIX A